ADVANCED DISTRIBUTED SIMULATION TECHNOLOGY II (ADST II)

DISMOUNTED WARRIOR NETWORK ENHANCEMENTS FOR RESTRICTED TERRAIN (DWN ERT) DO #0055

CDRL AB01

DWN ERT FINAL REPORT

FOR: NAWCTSD/STRICOM
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DOCUMENT CONTROL INFORMATION

Revision	Revision History	Date
	Original release	9/30/98
A	Revised to correct errors and respond to STRICOM comments – see attached errata sheet	11/30/98
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Errata Sheet for Revision A

Page	Change
19	Revised Table 2.1.8-1 removing cost data
26	Reworded VIC Golf paragraph to remove reference to aiming symbol, which was not used
28	Deleted BFV from diagram since not used during USEX
31	Revised update rate for VICs Delta, Echo, and Golf to reflect worst-case rate of around 15 Hz
35	Deleted errant '3' and deleted personal names, substituting organization
40	Corrected figure number
43	Revised wording of last sentence in 1st paragraph of Section 4.3 to improve phrasing; changed 'is' and 'will be' in 1st paragraph of section 4.3.1 to 'was'.
44	Added 'routes' to parenthetical A & B in last sentence of paragraph just before Section 4.3.2. Deleted 'and stationary)' from sentence at bottom of page (left over from previous cut & paste)
45	Changed '48 targets were used' to '48 trials were generated' in second paragraph in Section 4.3.3
46	Changed 'VIC' to plural 'VICs' at top of page
49	Changed two instances of 'range' to 'distance' to avoid redundancy of wording
51	Modified Table 4.5-1: Spelled out 'Measure of Performance' in heading, added asterisk beside 'Targets Hit' in this column and added note at bottom indicating number of targets for these percentages. Added word 'shooting' to last sentence of first paragraph after the table. Added sentence to 2nd paragraph beginning with 'This result is contrary. . .' in response to STRICOM comments
52	Changed 'request' in second line to 'requested'.
53	Last sentence of first paragraph, changed 'this regard' to 'collision measures'. Third paragraph, added phrase 'used during these tests' to sentence describing McKenna database. Deleted blank line from 1st paragraph of Section 4.5.1.1
55	Moved 2nd paragraph of Section 4.5.2 to below figure; revised figure to hide lines behind observer 'eyeball'. Added last sentence of 2nd paragraph of 4.5.2.1, beginning with 'This issue of whether . . .'
57	Revised discussion of SSCP singularity issue to attempt to clarify, in response to STRICOM comments. Revised discussion of two figures on page to clarify which is being discussed.
58	Paragraph at top of page, added word 'statistically'.
59	First paragraph of Section 4.5.2.2, added word 'their' to reference of soldier's morale. Changed 'by' to 'but' in 3rd paragraph. Third paragraph added phrase 'since this is the measure used for the statistical analysis of the data' to the end of the sentence. Fourth paragraph, changed word 'above' to 'sighting' and added phrase 'a significant' in 1st line; changed 'VIC' to 'VICs' in 3rd and 6th lines; added phrase 'for IHAS versus combined' to last sentence. Last paragraph, deleted 's' from 'effects' in 2nd line; changed 'is' to 'are' in 3rd line.
60	Figure 4.5.2.2-1 caption, added target total '(out of 384)' in response to STRICOM comment.
61	Added target total to Figure 4.5.2.2-3 caption '(out of 96)' in response to STRICOM comment. Added target total to Figure 4.5.2.2-4 caption '(out of 512)'; added phrase 'if aiming errors were consistent' to 2nd line of paragraph before Section 4.5.3.
62	Changed 'effected' to 'affected' in 1st paragraph of 4.5.3. Added target total to Figure 4.5.3-1 caption '(out of 384)'
63	Reworked sentences in middle of first paragraph to improve readability. Added target total to Figure 4.5.3-2 caption '(out of 128)'
64	Added target total to Figure 4.5.3-3 '(out of 96)'
65	Added target total to Figures 4.5.3-4 caption '(out of 128)'. Middle of 1st paragraph of Section 4.5.4, changed 'pretty much' to 'basically' and 'not found' to 'missed'.
66	Added 'Percent' to caption of Figure 4.5.4-1.
67	Revised 1st two sentences of 3rd paragraph to improve clarity.
69	Added '(seconds)' to Figure 4.6.1-1 caption.
71	Corrected x axis label of graph in Figure 4.6.2-3 to read 'Target Speed' instead of 'Target Azimuth Offset'
72	Reversed graphs so they would match corresponding captions
74	Changed 'Golf'' to 'Golf's' in 1st paragraph of Section 4.7.3.

Page	Change
75	Revised Table 4.7.5-1 as on page 51 above
76	Deleted the word ‘solely’ from 1^{st} paragraph of Section 5.1
77	Added word ‘alone’ to the last sentence of 3^{rd} paragraph of Section 5.3. Deleted phrase ‘As noted,’ from 1^{st} sentence of 4^{th} paragraph. Added 5^{th} paragraph on radio network.
81	Deleted ‘final’ from before ‘report’ at end of fourth sentence in 1^{st} paragraph of Section 5.4.2.
82	Added phrase in italics explaining which battery was being discussed (1^{st} paragraph). Deleted phrase ‘Unsolicited Editorializing’ from beginning of 1^{st} sentence in 3^{rd} paragraph.
85	Changed font size and lettering to numbering in numbered list in Section 5.5.
B-3	Corrected Table of Contents for Experiment Plan to fix ‘Bookmark not defined’ errors

Table of Contents

EXECUTIVE SUMMARY

Several years ago the Dismounted Battlespace Battlelab (DBBL) and the US Army Infantry Center (USAIC) identified the need for immersive virtual simulation. In February of 1994 DBBL hosted an Individual Combatant and Simulation Symposium to focus attention on the "... critical requirement to improve the representation of Individual Combatants across all modeling and simulation domains, for the purpose of improved Warfighting, Training, and Combat Development." These requirements prompted the Simulation Training and Instrumentation Command (STRICOM) to articulate the need for DWN in the Individual Combatant Simulation Technology Transfer Plan in November of 1995. This in turn resulted in the original DWN project, awarded under STRICOM's ADST II contract in June, 1996. Lockheed Martin is the prime contractor and system integrator for ADST II.

The primary objective of this project was the integration of a number of existing virtual simulation systems into an interoperable network of individual soldier simulators and simulations. Virtual Individual Combatant (VIC) Simulators developed by STRICOM, TRAC-WSMR, NPS and NAWC-TSD were integrated with DI SAF, a modified version of the Marine Corps IC SAF, and installed at the Land Warrior Testbed (LWTB) at Fort Benning in May of 1997. See Figure 1.

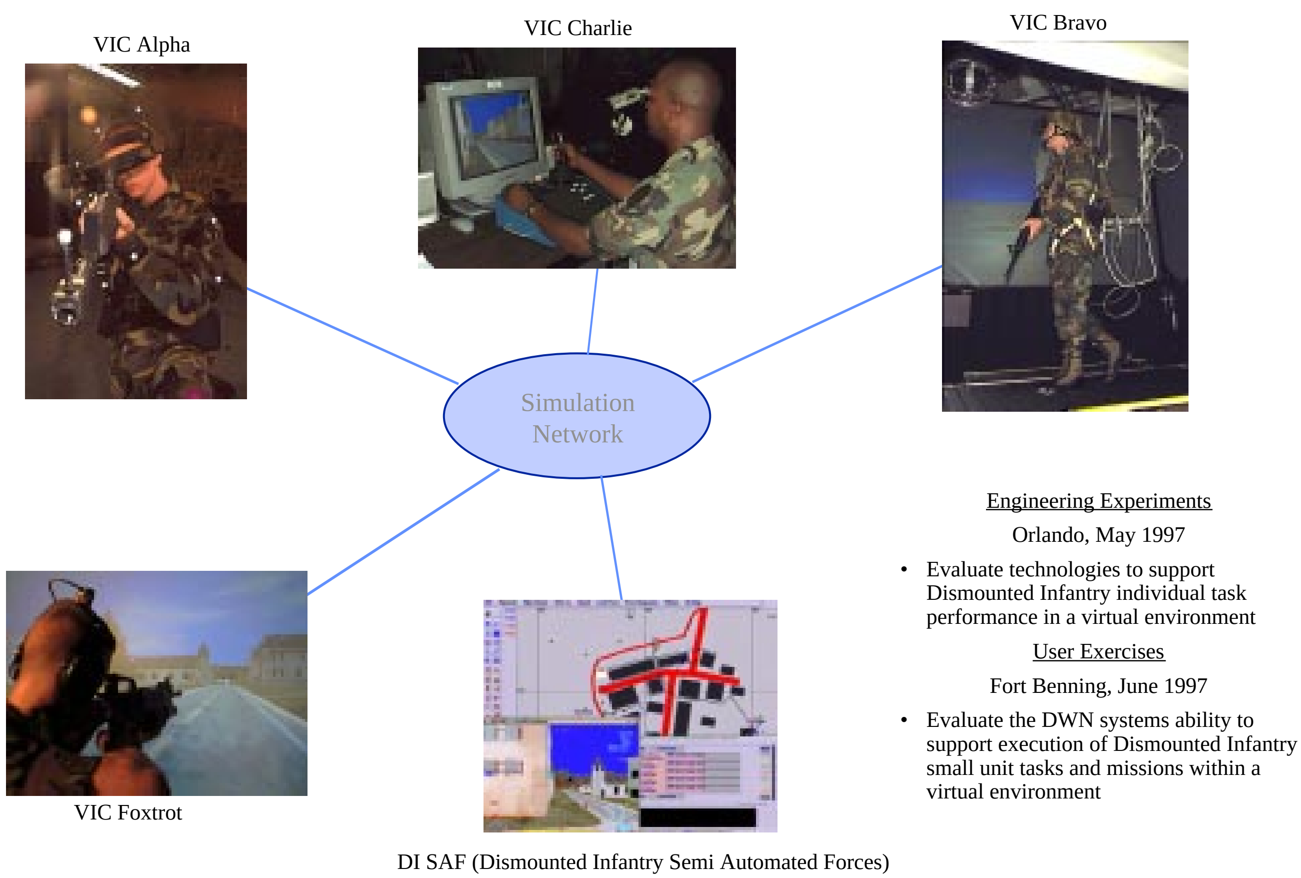

Figure 1: First Instantiation of Dismounted Warrior Network (DWN)

This first instantiation of the DWN was utilized to support an initial set of experiments in late May and early June 1997. These experiments have shown the value of the DWN to assess the utility of the emerging "immersive" simulation technologies. Combined with the comprehensive Simulation Task Analysis that was conducted as a parallel activity, the DWN program has made a good start at accomplishing its initial mission, the definition of requirements for IC simulation.

In September of 1997 a follow-on project was initiated, with a focus on Military Operations in Urban Terrain (MOUT). The new project was entitled DWN Enhancements for Restricted Terrain (DWN ERT). New low cost VICs recently acquired by DBBL were modified based on lessons learned in the first set of experiments. New locomotion methods were introduced, improved low-cost visual systems were incorporated, and new aiming techniques were implemented. In addition, the DI SAF was modified to support operations inside buildings. Experiments were conducted in July 1998 with these modified systems. See Figure 2.

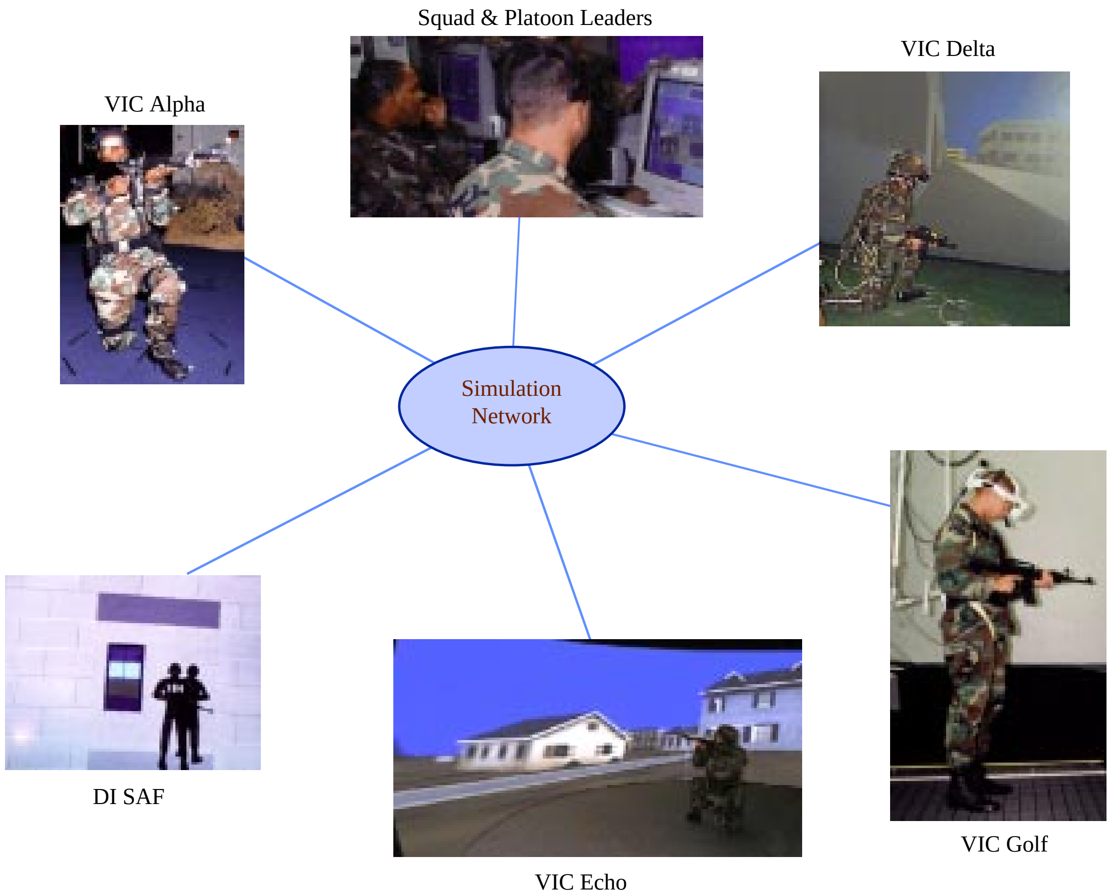

Figure 2: Current Instantiation of Dismounted Warrior Network (DWN)

MOUT Experiments

The goal of the latest round of experiments was to investigate how well a fireteam of VICs and DI SAF could support MOUT tasks at the individual soldier, fireteam, squad, and platoon levels. Nine MOS 11M Fighting Vehicle Infantryman from D Company, 1st Bn, 15th Inf Regiment, 3rd Bde, 3rd Infantry Division (Mechanized) at Fort Benning participated in the experiments.

The first week focused on engineering experiments – part-task simulations that separately investigated how well the VICs supported basic soldier tasks. These tasks consisted of walking through the environment, both inside and outside buildings, shooting at moving and stationary targets, and searching for and acquiring OPFOR DI targets both inside buildings and outside in a built-up environment (simulated McKenna MOUT site). Performance data collected from these tasks will support determination of how well the VICs' visual systems, mobility implementation, and weapon aiming performed as compared to one another.

Also during this week, the soldiers participated in one half-day session at the actual McKenna MOUT site at Ft. Benning. They performed several of the same tasks performed during the engineering experiments to serve as a basis of comparing performance in the VICs versus that in the real world. In addition, simulated building assault and room clearing operations were conducted to ensure all soldiers were familiar with proper techniques and tactics. This exercise also provided a baseline for comparison with the simulated assault and building-clearing mission to be conducted in the VICs the following week.

The second week of testing focused on assessing how the VICs supported coordinated fireteam, squad, and platoon level tactical operations. The mission scenario involved a platoon assault of a building within the virtual McKenna database. A hole was blown in the side of the building allowing the platoon ingress to the building. Once inside, the platoon performed clearing operations, searching for snipers located in various locations throughout the building. The platoon consisted of one mixed squad - one fireteam of VICs working with a fireteam of DI SAF - and one pure DI SAF squad. The soldiers took turns participating as VIC fireteam members. The primary data collected was soldier assessments of VIC utility gathered through ARI administered questionnaires and interviews.

Analysis of the data collected during the experiments is presented in Sections 4 and 5 of this report. Preliminary assessments indicate that the fidelity of the immersion in the synthetic environment was "good enough to suspend disbelief " such that the soldiers were fully engaged in the mission at hand. Technical improvements are still needed in the areas of weapon aiming and in visual scene detail, among others, but the potential of virtual simulation to support DoD M&S needs was demonstrated.

Technology Assessment

The technologies and systems required to fully immerse the infantryman in the virtual environment are not fully matured. Movement through the synthetic environment, whether by joystick mounted on the rifle, or the omni-directional treadmill, is difficult in close quarters, such as inside buildings. The locomotion control mechanisms require more work to give the soldier better dynamic range of control, so he can move in very small increments. The feedback control software on the treadmill also requires more work before the soldier will be able to walk in something approaching a natural gait. The visual feedback, though improved from prior systems, does not consistently provide good depth cues to the soldiers, especially inside buildings. For example, it is sometimes difficult to distinguish a cinder block wall in the hallway from a cinder block wall in the back of a room that is visible through an open hallway door. Further, there is no tactile feedback - the soldier cannot lean up against a wall, or bump into another fireteam member, and receive the physical, tactile feedback he would receive in the real world. Collision detection software prevents the soldiers from walking through a wall, but there is no corresponding physical feedback to corroborate his visual perception.

Immersion is much more difficult for the infantryman than for the traditional simulator user - the fighter pilot or the tank commander. Vehicles are easier to simulate because vehicles are the soldier's environment; the vehicle, not the soldier, interacts with the synthetic environment. The vehicle simulation can be tricked into believing it is moving on real ground via motion platforms and sophisticated software. But tricking the human to believe he is interacting with real objects, even walking on the ground, is a far different matter.

Even given the fact that many technical challenges remain before DI simulators achieve the level of performance found in many of the vehicle simulators, these simulations have come a long way in the short span of the DWN program. Performance in computing power, graphics fidelity, and wide field of view display resolution have all improved with a corresponding reduction in cost. The development partners participating in DWN have brought their visions of DI simulation to the user and let them be put to the test. Their participation involved personal and business risk, and we believe that the experiments have shown that as these simulators continue their development, they are homing in on target.

We also believe that there are applications that exist today which could benefit from the application of existing and near-term individual combatant oriented virtual simulation systems. Some examples are given below.

<u>Applications</u>

Advanced systems such as Land Warrior (LW) and Objective Individual Combat Weapon (OICW) are for the most part being developed with the aid of engineering (physical) and constructive (analytic) simulations. Prototypes are built, tested, modified, tested again, and so forth. Virtual simulations such as DWN could aid these developments via a "simulate-test-simulate" paradigm. This is also referred to as virtual prototyping, or more recently, simulation-based acquisition. A new weapon or even a design change to a new weapon system is proposed, and before any physical prototyping occurs, the idea is simulated and tested. This approach can't prove that an approach will work, but it can prove that something won't work, thus allowing the developers to move onto the next approach before wasting any more time and money. And it can suggest that a new approach might work and therefore ought to be considered further.

Though not designed for precision gunnery training, DWN could be used to support the development of training doctrine for advanced systems, such as LW and OICW. Once fielded, virtual simulators modified with high fidelity LW and OICW simulations could be used to provide individual and collective training. When these complex systems are fielded virtual simulators may well prove to be just as cost effective for training as aircraft and tank simulators are today.

Another potential application of IC virtual simulation is the collection of performance data that would otherwise be difficult to generate. For example, the U.S. Army Materiel Systems Analysis Activity (AMSAA) recently conducted an experiment at the LWTB to collect "quick-kill" performance data in a MOUT environment. AMSAA was interested in estimating the probabilities of hit, kill, and exposure for close engagements; DWN provided a means to collect this data.

Summary

Virtual simulation technology, though still not fully matured, has intrinsic value for a number of IC simulation applications. Virtual simulation does not replace other simulation tools, rather it can help to fill in the gaps that currently exist in the engineering, constructive and live simulation domains and save developers time and dollars.

The DWN systems described in this report are permanently housed at the Land Warrior Testbed in a Government Owned Contractor Operated (GOCO) facility under the auspices of STRICOM and DBBL. In the near future additional VICs will be integrated into the LWTB, providing the Army with a true "Squad Synthetic Environment" aimed squarely at meeting the needs of the infantryman of the twenty-first century. These assets are available to serve the needs of DoD.

This report serves to document what has happened during the ERT phase of the DWN program. As such, it tends to be backward looking, recording successes, failures, and lessons learned. A balancing look to the future is needed, applying the lessons learned and identifying ways to overcoming the shortcomings uncovered with the current generation of DI simulators. This look ahead will be supplied by the Capstone Study that was tasked in the DWN Contract Mod #10. Its intent is to capture the lessons learned from both phases of DWN, to tie these back to the simulation task analysis to the extent possible, and to project ahead to what should be done to the VICs and DI SAF to establish a solid foundation upon which future simulation systems can be built. For whatever shortcomings exist at present, the future most certainly will include manned and SAF dismounted infantry simulations that will be applied across variety of training, research, and development activities.

1.0 Introduction

This report documents the work performed under the Dismounted Warrior Network Enhancements for Restricted Terrain (DWN ERT) Delivery Order (DO), #0055. The Army's Simulation, Training and Instrumentation Command (STRICOM) awarded the DWN ERT DO on September 4, 1997. The technical effort is scheduled to be completed by March 30, 1999. As prime contractor, Lockheed Martin Information Systems (LMIS) had overall project responsibility, but the project would not have succeeded without the dedicated efforts of many organizations from industry and the government. The contributions of the following organizations are gratefully acknowledged.

Industry Partners:
Boston Dynamics Inc. (BDI)
Reality By Design (RBD) Government Systems LLC
Resource Consultants Inc. (RCI)
Science Applications International Corp. (SAIC)
Soft Reality Inc.
Veda Inc. (now Veridian)

Government Partners:
Army Research Institute (ARI)
Army Research Lab (ARL)

1.1 Background

Several years ago the Dismounted Battlespace Battlelab (DBBL) and the US Army Infantry Center (USAIC) identified the need for immersive virtual simulation. In February of 1994 DBBL hosted an Individual Combatant and Simulation Symposium to focus attention on the "... critical requirement to improve the representation of Individual Combatants across all modeling and simulation domains, for the purpose of improved Warfighting, Training, and Combat Development." These requirements prompted the Simulation Training and Instrumentation Command (STRICOM) to articulate the need for DWN in the Individual Combatant Simulation Technology Transfer Plan in November of 1995. This in turn resulted in the DWN project, awarded under STRICOM's ADST II contract in June, 1996. Lockheed Martin is the prime contractor and system integrator for ADST II.

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This first instantiation of the DWN was utilized to support an initial set of experiments in late May and early June 1997. These experiments have shown the value of the DWN to assess the utility of the emerging "immersive" simulation technologies. Combined with the comprehensive Simulation Task Analysis that was conducted as a parallel activity, the DWN program has made a good start at accomplishing its initial mission, the definition of requirements for IC simulation. This work is described in detail in the DWN Final Report, document number ADST-II-CDRL-DWN-9700392A [ref 2.4.2.g].

Near the end of the DWN project a number of discussions were held with STRICOM and DBBL to discuss requirements for a follow-on DWN project focused on meeting IC simulation needs for MOUT environments. The project title DWN Enhancements for Restricted Terrain (DWN ERT) was created to reflect this interest in MOUT. STRICOM commissioned LMIS to perform a study to assess the state of the art in IC simulation technologies and to recommend alternative tasks for the follow-on DWN ERT Delivery Order. This study was titled “Requirements Analysis for DWN ERT”, and Revision A was published on July 14, 1997; the document number is ADST-II-MISC-DWN-9700240A [ref 2.4.2.b]. This study formed the basis for the DWN ERT DO.

1.2 DWN ERT Approach and Objectives

The overall approach was to enhance the DWN assets delivered to the LWTB at the conclusion of the June 1997 DWN User Experiments. The enhancements were intended to facilitate the use of the DWN to support US Army and Marine Corps Advanced Concepts and Requirements/ Research, Development and Acquisition (ACR/RDA) objectives as they relate to Individual Combatants (IC) involved in Military Operations in Urban Terrain (MOUT). Within RDA, special emphasis is placed on meeting the simulation needs of the MOUT ACTD. Within ACR, the enhanced DWN system is intended to support concept development, technology evaluation, materiel evaluation, doctrine, tactics, combat techniques, and force structure for IC MOUT applications.

Specific project objectives were stated as follows:

a) Enhance the DI SAF with MOUT capabilities.

b) Enhance the existing VIC simulators to support MOUT needs, including but not limited to Land Warrior IHAS and C4I capabilities, virtual radios and miscellaneous equipment such as flyboxes.

c) Upgrade and enhance the McKenna MOUT database.

d) Develop next generation VIC simulator(s) with capabilities including but not limited to head mounted displays, wide field of view curved displays, higher performance visuals, and improved head/weapon tracking performance.

e) Continue the operation of the DWN web site.

f) Implement a dynamic terrain capability.

g) Integrate the enhanced VICs and SAF at the LWTB.

h) Perform experiments at the LWTB to evaluate the DWN MOUT enhancements.

i) Write final reports for the overall project and for the DI SAF effort.

The development tasks that are described in Section 2.0 of this report were derived from these objectives and from a MOUT task analysis that was drawn from the Task Analysis reports developed for the DWN DO. In addition, a MOUT scenario based on Army doctrine was developed and used to help ensure a logical consistency between requirements (see Appendix B for a detailed description of the scenario).

1.3 Deliverables

The deliverables consist of hardware, software and CDRLs.

1.3.1 Hardware and Software

The hardware and software deliverables and their disposition are tabulated in Table 1.3.1-1. Many of the deliverables in this table consist of components developed under other government contracts.

Table 1.3.1-1: Hardware and Software Deliverables

Deliverable Item	Provider	Disposition of Item	Ownership
VIC Alpha DSS	Veda	System stays at LWTB	Gov't
VIC Delta SVS + Real3D	RBD, LM	Systems stay at LWTB	Gov't
VIC Echo SVS + Real3D + Dome Display	RBD, LM	Systems stay at LWTB; dome display owned by LMIS, on loan to LWTB	Gov't + LMIS
VIC Golf SVS + Real3D + ODT + HMD	RBD, LM	System moved to ARL; but SVS screen, projector, 1 PC stay at LWTB; SGI development platform stays at RBD on loan from LWTB	Gov't
BAYONET BAYONET + Fly-Boxes (2)	RBD, LM	Systems stay at LWTB; RE2 development system remains at RBD on loan	Gov't
SAF DI-SAF	SAIC, LM	Development hardware remains in Orlando for use by SAIC (2 Indys + Max. Impact); latest software installed at LWTB	Gov't
Virtual Radios ASTI	LM	DIS Compliant virtual radio network to support 8 users stays at LWTB	Gov't
Animation Software DI Guy	BDI	Site license for 10 simultaneous users of DI Guy software stays at LWTB; one copy in OSF for use by DI SAF team	Gov't

1.3.2 CDRLs

Eleven CDRLs were required for the DWN Delivery Order. They are tabulated in Table 1.3.2-1. The CDRLs will be posted to the DWN web site, which can be found at the web address: "http://www.stricom.army.mil/PRODUCTS/DWN/".

Table 1.3.2-1: DWN ERT CDRLs

CDRL #	Description	CM Number	Date
AB01	DWN ERT Final Report	ADST-II-CDRL-DWNERT- 9800258	11/30/98
AB02	DI SAF MOUT Enhancements Final	ADST-II-CDRL-DWNERT- 9800259	09/30/98

CDRL #	Description	CM Number	Date
	Report		
AB03	DWN AUSA Display and Demonstration Summary Report	ADST-II-CDRL-DWNERT-9700516	12/12/97
AB04	DWN 3D Visualization for MOUT Summary Report	ADST-II-CDRL-DWNERT- 9800260	12/30/98
AB05	DWN DI SAF Support Summary Report	ADST-II-CDRL-DWNERT- 9800091	05/30/98
AB06	DWN ModSAF Baseline Documentation	ADST-II-CDRL-DWNERT- 9800261	09/11/98
AB07	DWN ModSAF Baseline and System Enhancement Summary Report	ADST-II-CDRL-DWNERT- 9800262	09/30/98
AB08	Results of Analysis for STOW-A SOAR(A) Training Exercise	ADST-II-CDRL-DWNERT- 9800124	04/30/98
AB09	DWN Capstone Study	ADST-II-CDRL-DWNERT- 9800263	12/30/98
AB10	DWN Capstone Study Summary Report	ADST-II-CDRL-DWNERT- 9800264	03/30/99
AB11	DWN R40 Summary Report	ADST-II-CDRL-DWNERT- 9800265	12/30/98

1.4 Applicable Documents

1.4.1 Government

a) Statement Of Work For Dismounted Warrior Network Enhancements for Restricted Terrain (DWN ERT) DO, AMSTI-97-W062, Rev D, dated 21 August 1998.

b) SOW Appendix A to DWN ERT, AUSA Support, Rev B, dated 7 January 1998.

c) SOW Appendix B to DWN ERT, 3D Visualization for MOUT, Rev B, dated 17 June 1998.

d) SOW Appendix C to DWN ERT, DI SAF Support, Rev C, dated 7 January 1998.

e) SOW Appendix D to DWN ERT, ModSAF Baseline and System Enhancements, Rev B, dated 7 January 1998.

f) SOW Appendix E to DWN ERT, STOW-A 160th SOAR(A) Training Exercise, dated 27 February 1998.

g) SOW Appendix F to DWN ERT, Capstone Study, Rev A, dated 4 August 1998.

h) SOW Appendix G to DWN ERT, R40 Virtual Planner, Version 2.0, dated 11 September 1998.

1.4.2 Non-Government

a) Technical Approach for Delivery Order # 0055, DWN ERT, Rev H, dated 18 June 1998.

b) Lockheed Martin, “Requirements Analysis for DWN Enhancements for Restricted Terrain, Revision A”, document number ADST-II-MISC-9700240A, dated July 14, 1997.

c) “Standard For Interactive Simulation Protocols For Distributed Interactive Simulation Applications Version 2.0 (Fourth Draft)”, 3 February, 1994.

d) Evans, Alan, Stanzione, Tom, et. al., “Multiple Elevation Structures in the Improved Computer Generated Forces Terrain Database”, 1996.

e) Soft Reality, “ADST II DWN ERT DI C4I Simulation Software”, dated March 23, 1998.

f) Lockheed Martin, “3D Stealth Viewer Evaluation”, briefing charts dated 9-25-97.

g) Lockheed Martin, “DWN Front End Analysis Experiments Final Report”, document number ADST-II-CDRL-DWN-9700392A, dated December 12, 1997.

h) Reece, Douglas A. and Dumanoir, Paul, “Conventions for Representing Humans in a DIS Exercise: The DWN Experience” 1998.

1.5 Document Contents

This document is the Final Report for the DWN ERT Delivery Order. As such, it encompasses all of the work performed on the DO to date. However, the treatment on the DI SAF development effort is cursory because it is covered in detail in CDRLs AB02 and ABO6. In addition, the Capstone Study effort is documented separately in CDRLs AB09 and AB10 since the work was still ongoing after this report was written. Similarly, the R40 Virtual Planner effort is still ongoing, therefore it is documented in CDRL AB11.

The remainder of this document is organized as follows:

2.0 DWN Development Tasks and System Description

2.1 DWN ERT Development Tasks

The DWN ERT DO was awarded on September 4, 1997. The initial scope of the contract included the following: DI SAF Enhancements, VIC Simulator Enhancements, McKenna MOUT Database Enhancements, Next Generation VIC Simulator, DWN Web Site Operations, Dynamic Terrain Simulation, and DI C4I Simulation, culminated by a set of experiments at Fort Benning. As the DO progressed, additional tasks were added to DWN ERT as contract modifications; these included AUSA Support, 3D Visualization, DI SAF Support, ModSAF Baseline & System Enhancements, STOW-A 160th SOAR(A) Training Exercise, Capstone Study and Virtual Planner. Each is briefly described in the following paragraphs.

2.1.1 DI SAF Enhancements (SOW paragraph 3.1.2.1)

The DWN DO resulted in a DI SAF capability whose focus was open terrain. The DWN ERT DO modified the DI SAF to support MOUT scenarios. In the prior implementation, buildings were simply obstacles to the DI SAF entities. They could not be entered, seen through, or shot through. The behaviors to support operations in and around buildings were also lacking. In addition, DI SAF did not model some individual soldier weapon systems that were required to blow mouseholes in walls (e.g., the AT4 weapon system).

In order to provide the necessary enhancements to DI SAF the DWN ERT team built on the Multiple Elevation Surfaces (MES) work done by the Computer Generated Forces Terrain Database (CGFTB) project [ref 1.4.2.d]. MES models buildings as structures containing apertures and enclosures. An enclosure is used to model a room, and an aperture is used to model doors and windows that are part of a room. MES relies on a topology for a building that identifies apertures with enclosures, and enclosures with sub-enclosures. The main extensions that were added were the modeling of dynamic apertures, specifically mouseholes and breached doors/windows.

MES provides the necessary data structures, but not the MOUT behaviors - the behaviors, which model the movements and actions that the SAF take in and around the buildings. The necessary behaviors were developed by first developing the necessary MOUT CISs, or Combat Instruction Sets. These CISs were developed via the same approach that was used successfully on the CCTT program for developing vehicle-oriented behaviors. The CISs included clear traceability to US doctrinal and tactical references. In addition, these CISs were verified and validated by contractor subject matter experts, and face validation provided by the government.

DI SAF development efforts are covered in detail in CDRL AB02, DI SAF MOUT Enhancements Final Report.

2.1.2 VIC Simulator Enhancements (SOW paragraph 3.1.2.2)

VIC Alpha and BAYONET were modified to support the MOUT experiments and DI Guy software licenses were obtained as described below.

2.1.2.1 VIC Alpha

VIC Alpha was modified to work with the DWN virtual radios and to simulate IHAS imagery in the HMD. In addition, VIC Alpha was shipped and installed at the LWTB prior to the start of System Integration.

2.1.2.2 BAYONET Stations

Two BG flyboxes were procured to provide joystick control of the two BAYONET stations used for the Platoon Leader and the Squad Leader.

2.1.2.3 Animation Software Licenses

A site license was acquired for DI Guy software. This site license is for run-time licenses only, and covers up to 10 systems, which can be any mix of PCs, Real3D Pros, and SGI workstations. The licenses will not time out, and they can float between different machines, as long as no more than 10 are active at one time. We also acquired two DI Guy development licenses for the Real3D Pro.

2.1.3 McKenna MOUT Database Enhancements (SOW paragraph 3.1.2.3)

A number of database modifications were made to the McKenna MOUT site database to enhance its utility for DWN MOUT simulation. They included the following:

a) A 2km by 2km patch was extracted from the original government supplied 4km by 4km high resolution inset, centered on the McKenna MOUT site.

b) The database was updated to match the recent construction at the MOUT site, including colors, textures, new doorways, and introduction of rubble, with emphasis on those features that would support the experiment scenario.

c) Level of detail modeling was added to improve the update rate for the various visual systems employed in DWN.

d) The texture maps on the ground and on the floors and stairwells were enhanced to improve spatial cueing for the VIC soldiers.

This work was preceded by a data capture trip to the McKenna MOUT site, and included database reviews with STRICOM and DBBL at each of the TIMs. Videotape and still pictures were collected from McKenna. All database modeling work was done in the OSF using ADST II MultiGen software tools.

Background

The McKenna MOUT database was originally developed by the government, based on aerial photos, maps, blueprints, and ground surveys; details are provided in "Final Report of the MOBA Terrain Database Project" which can be found on the Internet at http://www.tmpo.nima.mil/news/moba.html.

The goal of this project was to "...create a database limited by the availability of the source data, rather than the existing limitations of current real-time graphics and CGF systems." Thus, 1:5000 scale aerial photography was used in the highest resolution areas of the database, which permitted digital elevation models as good as 1-meter resolution to be created. When measured against GPS survey points, the MOBA report showed the 1 meter DEM to be within 1 meter of the survey points at the 90% confidence level.

During database production, the DEM was triangulated into a TIN (Triangulated Irregular Network) and converted into S1000 format; we observed that the average edge of the terrain triangles that resulted from this process to be about 100 meters; triangles of a higher density would have resulted in a prohibitively large number of polygons (i.e., too many to render by the available image generators). No measurements were reported for elevation accuracy after triangulation, but we would expect a non-trivial fall-off from the raw DEM 1-meter posting errors.

Feature location in terms of absolute horizontal error was reported to be about 4 meters at the three-sigma point. It was noted that when these features were converted into database features in S1000 format, the errors increased slightly.

The government converted the S1000 database into MultiGen OpenFlight format. The database was 24 km by 24 km in size, with a 4 km by 4 km high resolution inset. This was the starting point for the DWN project.

<u>Accuracy</u>

Resolution of the database in OpenFlight is .001 meter; accuracy varies within the database, per the following discussion:

a) With regard to the elevation surface, we used the TIN supplied by the government without modification. We did not measure elevation errors, but they should be no worse than the original TIN produced by the government.

b) Building locations were not changed from the government supplied coordinates, although we noted during field observations that some locations were in error by as much as several meters (consistent with the government error analysis) and some of the buildings were not quite aligned correctly (also consistent with the government error analysis).

c) A significant amount of effort went into the correction of the geometry and textures within each building. Photos were taken to create textures, and measurements were made with a tape measure to check the location of every door and window in the McKenna buildings. We believe that the accuracy within each building to be 6 inches or less, measured to a common point within the building (i.e., relative error).

d) The main roads in and around the McKenna MOUT Site were unchanged from the roads supplied in the original S1000 database. Therefore these features should display an absolute error of slightly more than 4 meters, as described above.

e) All other ground features - side roads, paths, trees, telephone poles, fences, shrubs, etc. - were located by using tape measures and by visually estimating distances relative to the closest building.

Therefore these features should display the same absolute horizontal error of about 4 meters. We estimate relative horizontal error to be about a foot or less; i.e., relative to the nearest building.

2.1.4 Next Generation VIC Simulator (SOW paragraph 3.1.2.4)

Three Soldier Visualization Systems (SVS) were previously acquired by DBBL. They were used as the front end for VIC Delta, VIC Echo and VIC Golf. See Figure 2.1.4-1.

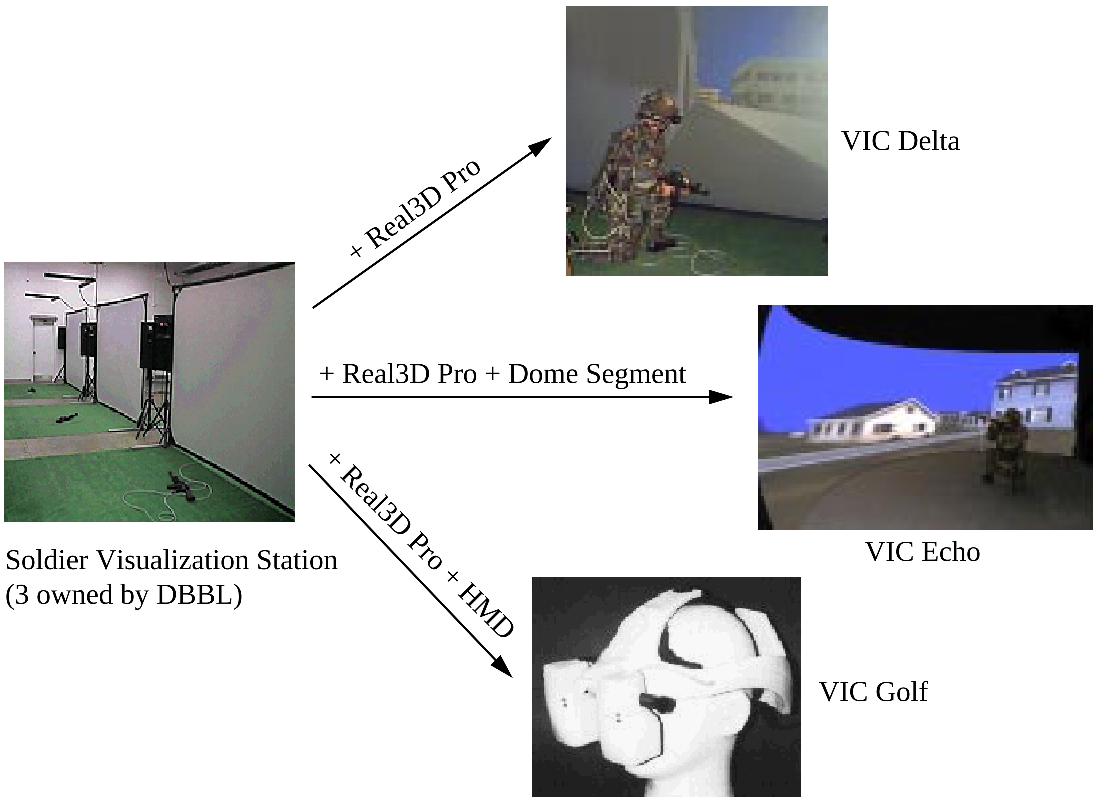


Figure 2.1.4-1: Soldier Visualization Systems were used for VICs Delta, Echo and Golf

The SVS is described in paragraph 2.1.4.1. The enhancements to the SVS to yield VIC Echo are described in paragraph 2.1.4.2. The SVS enhancements for VIC Delta and VIC Golf are described in paragraph 2.1.8.4.2.

2.1.4.1 Soldier Visualization System (SVS)

As stated above, the SVS was used in VICs Delta, Echo and Golf. In addition, the SVS for all configurations was modified to support Dynamic Terrain and to support DI C4I. These modifications are described in paragraphs 2.1.6 and 2.1.7, respectively. The SVS as it was originally received from DBBL is briefly described below.

The SVS is a PC based man-in-the-loop Distributed Interactive Simulation (DIS) system geared toward individual combatants. It provides two simultaneous channels of computer generated imagery: one for the regular IC view of the synthetic environment, and one for presentation via the IHAS (or similar) display. A surrogate Land Warrior rifle is instrumented and connected to the SVS system. Navigation is achieved via a thumbswitch located on the grip of the rifle. Two trackers provide position and orientation information - one located on the surrogate rifle and one located on the IC helmet. Spatialized battlefield audio is presented to the participant via speakers. The SVS supports display of the regular IC view of the synthetic environment via rear screen projection.

Hardware components:

a) Two 200Mhz, Pentium Personal Computers, each configured with 128M of RAM, 2GB disk, 3D graphics accelerator board, sound card, preloaded and preconfigured with RBD's proprietary software;

b) Two external, self-powered speakers;

c) One Land Warrior surrogate rifle instrumented with functioning triggers, buttons and thumbswitch;

d) An Intersense tracking system;

e) One video projection system capable of delivering a 640x480 or 800x600 resolution image;

f) One projection screen with a minimum 6'x 6' dimensions capable of rear projection.

Software capabilities:

a) Generation of a three-dimensional computer graphics, simulated soldier's view into the virtual battlefield presented at a 640x480 or 800x600 image resolution;

b) Generation of a 3d simulated rifle view presented as a 640x480 resolution image;

c) Capability for the soldier to move, interact and operate in the virtual battlefield, including aiming, lasing and firing the LW mockup rifle;

d) Computation and presentation of spatialized audio;

e) Tracking of the rifle and soldier's position and posture;

f) Networked transmission of the soldier's position, posture and state using DIS 2.0.4 protocols; and

g) Software linkages to the DI C4I system via a TCP/IP connection.

2.1.4.2 VIC Echo

VIC Echo has functionality similar to VIC Delta (see paragraph 2.1.8.4.2) but with a different display system: a curved screen (i.e., a dome segment) with projectors and improved field of view and resolution as compared to VIC Delta. VIC Echo is therefore described as a VIC Delta system with modifications to provide a wide FOV display on a 150-degree by 40-degree dome segment and high-resolution Barco projectors. The display system was provided by LM at no cost to the project via a long-term loan (other than shipping and set-up costs). It also includes 2 Real3D Pros to drive the Barco projectors. Figure 2.1.4.2-1 illustrates.

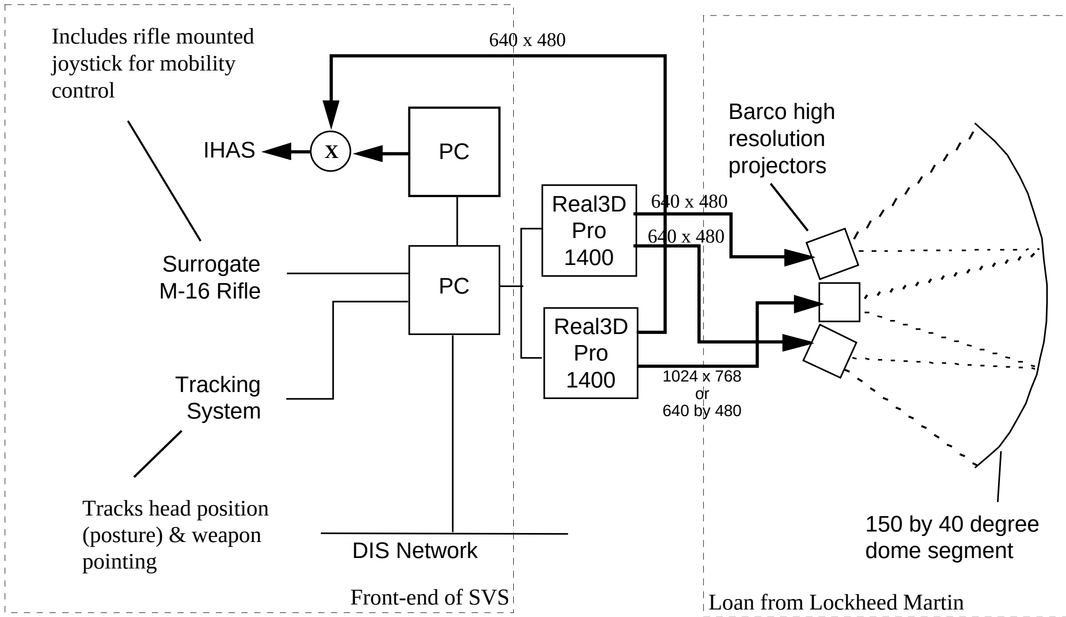


Figure 2.1.4.2-1: VIC Echo Block Diagram

2.1.5 DWN Web Site Operations (SOW paragraph 3.1.2.5)

The DWN web site was maintained with "minimal support" from September 1, 1997 through February 27, 1998. "Minimal support" included the posting of meeting minutes, briefing materials, occasional documents, announcements, and so forth. In March of 1998 the hardware and software associated with the web site was turned over to STRICOM, at which time STRICOM took over maintenance of the DWN web site. The new web site address is "http://www.stricom.army.mil/PRODUCTS/DWN/".

2.1.6 Dynamic Terrain Simulation (SOW paragraph 3.1.2.6)

Two types of dynamic terrain were implemented: mouseholes and breaching of doors and windows. We utilized the Army Research Lab (ARL) approach to dynamic terrain, in which the mousehole is created at the impact point by simply modifying the polygons that comprise the surface where the impact occurred. The surface polygons are read from the OpenFlight database, new polygons are created to match the shape and size of the old surface but with a hole at the impact point, then the new polygons are written back into the OpenFlight database. No new PDUs were required to implement DT in DWN; all participants agreed on the size of the hole to be created by a given weapon, and modified their systems to respond appropriately when the detonation PDU was received indicating that a hole is to be blown. We utilized the AT-8 (a variant of the AT-4) to create the mouseholes.

Each VIC was modified with the ARL algorithm, which simply creates a hole of a pre-determined size at a point on the surface of a wall, ceiling, or floor, as specified by the Detonation PDU. The DI SAF was also modified to respond to this Detonation PDU, and to create a hole of the proper size and location in the MES data structures. The DI SAF modifications are described in CDRL AB02, DI SAF MOUT Enhancements Final Report.

Breaching a door or window results in the removal of the door/window from the simulation. As with mouseholes, it is the responsibility of each simulator to listen to the Detonation PDU, and if it impacts a door or window, the feature is removed from its database. VIC' and SAF are able to breach doors/windows, and to detect that a door/window has been breached. The SAW was made capable of breaching doors or windows along with the AT-8.

2.1.7 DI C4I Simulation (SOW paragraph 3.1.2.7)

A DI C4I simulation was developed for DWN ERT. LMTSG subject matter experts were utilized to help design the screen layouts and functionality. The approach was loosely based on the Land Warrior C4I design, so we refer to it as "DI C4I".

For this first instantiation five (5) DI C4I simulation sets were built - two run on standard PC monitors co-located with two BAYONET stations, two run on the simulated IHAS of VIC Delta and VIC Echo, and one runs on a standard PC co-located with a BLUFOR SAF Operator. Each simulation ran on a PC that was connected to the DIS network. The DIS network is used as a virtual VMF network; i.e., VMF data is packaged into DIS Data PDUs and transmitted over the DIS network. Figure 2.1.7-1 illustrates.

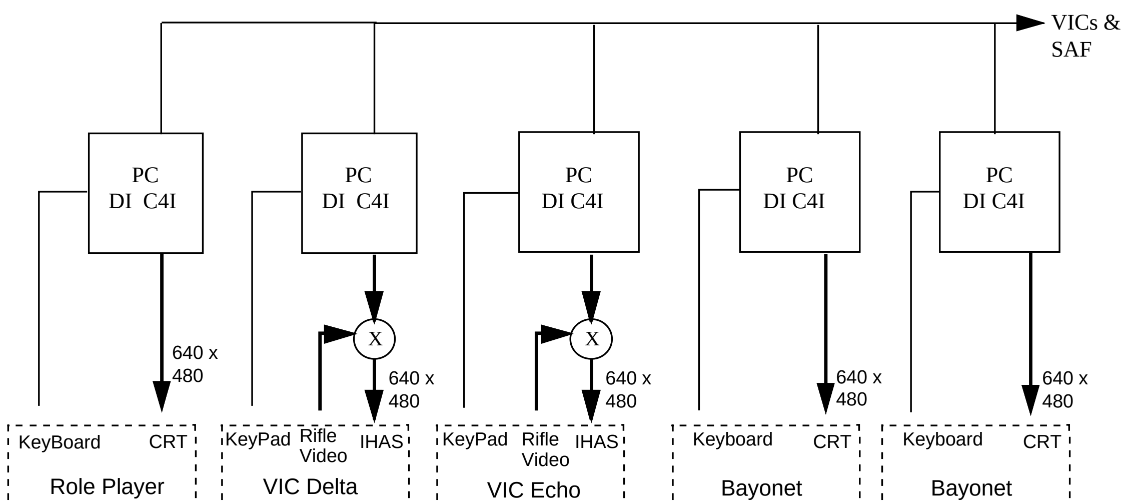


Figure 2.1.7-1: DI C4I Simulation Block Diagram

For this initial implementation four types of screens were developed: Send Report (which has several sub-types), Receive Report, Map (PVD), and Video (from IG simulating rifle video). Send Reports can include enemy locations that may be input automatically based on a laser range finder function performed by the host VIC. Figure 2.1.7-2 illustrates. A DI C4I User Manual was prepared and delivered to the LWTB [ref 2.4.2.e].

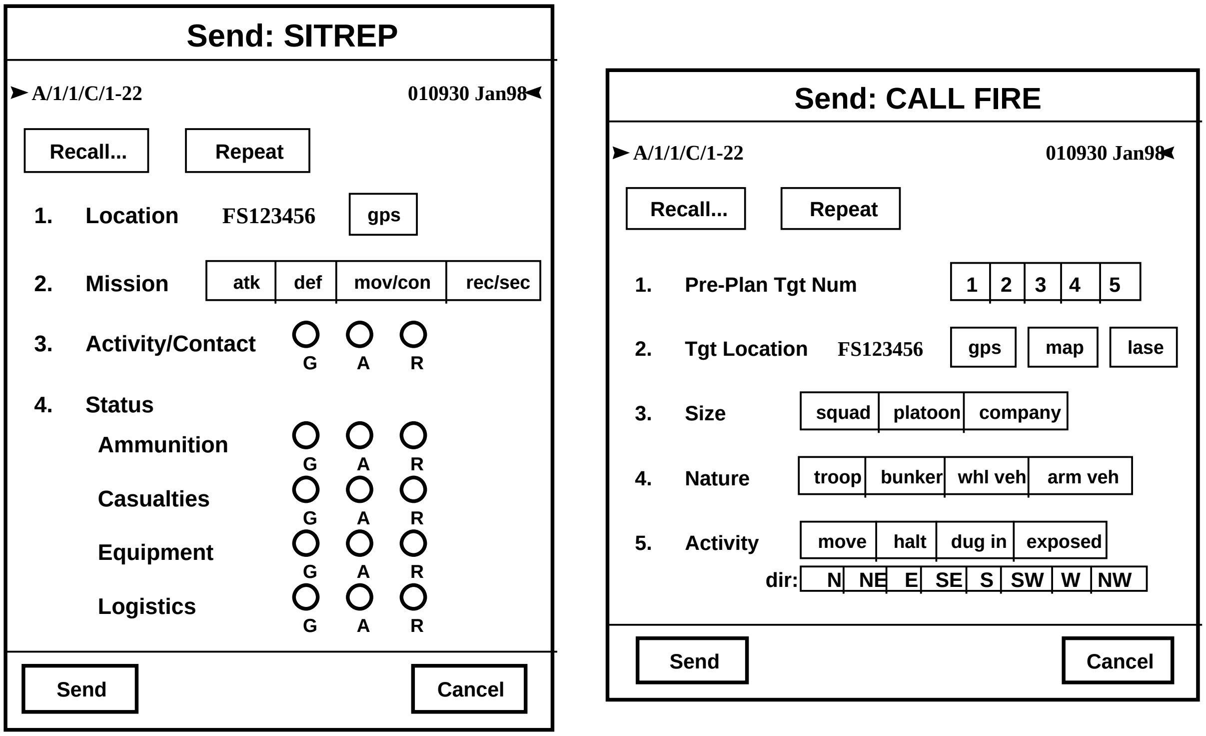


Figure 2.1.7-2: DI C4I Screens

2.1.8 Additional Tasks

The DWN ERT was modified several times to add new tasks to the project. These tasks included AUSA Support, 3D Visualization, DI SAF Support, ModSAF Baseline & System Enhancements, STOW-A 160th Special Operations Aviation Regiment (Airborne) Training Exercise, Capstone Study, and R40 Virtual Planner. Each is briefly described in the following paragraphs and summarized in Table 2.1.8-1.

Table 2.1.8-1: DWN ERT Contract Modifications

Event	SOW AMSTI-97-W062	Event Date	Start Date	End Date	Comments
DWN ERT Contract Award	SOW	4-Sep-97	4-Sep-97	31-Dec-97	DWN ERT Basic Contract
DWN ERT Mod 1	Appdx A	12-Sep-97	12-Sep-97	31-Dec-97	AUSA Support
DWN ERT Mod 2	Appdx B SOW Rev A	25-Sep-97	25-Sep-97	30-Jun-98	3D Visualization
DWN ERT Mod 3	n/a	30-Sep-97	4-Sep-97	30-Jun-98	Increase funding
DWN ERT Mod 4	Appdx A Rev A	4-Nov-97	4-Sep-97	30-Jul-98	DWN ERT + Mods 1 and 2
DWN ERT Mod 5	Appdx C Rev B	24-Nov-97	4-Sep-97	30-Jul-98	ModSAF Training & MES Editor
DWN ERT Mod 6	Appdx D Rev A	22-Dec-97	4-Sep-97	30-Jul-98	ModSAF Baseline & System Enhancements
DWN ERT Mod 7	SOW Rev B Appdx A Rev B Appdx C Rev C Appdx D Rev B	29-Jan-98	4-Sep-97	30-Jul-98	Documentation Clean-up
DWN ERT Mod 8	n/a	18-Feb-98	4-Sep-97	30-Jul-98	No change
DWN ERT Mod 9	Appdx E	12-Mar-98	4-Sep-97	30-Jul-98	Fort Campbell Mod
DWN ERT Mod 10	Appdx F SOW Rev C	27-Mar-98	4-Sep-97	30-Jan-99	Capstone Study Mod
DWN ERT Mod 11	Appdx B Rev A	30-Apr-98	4-Sep-97	30-Jan-99	3D Visualization Mod
DWN ERT Mod 12	n/a	26-May-98	4-Sep-97	30-Jan-99	Administrative Change
DWN ERT Mod 13	n/a	23-Jun-98	4-Sep-97	30-Jan-99	Change CDRL Dates AB02, 05, 06, 07
DWN ERT Mod 14	Appdx G Ver 1.0	8-Jul-98	4-Sep-97	30-Jan-99	R40 Mod AB11 added
DWN ERT Mod 15	n/a	4-Aug-98	4-Sep-97	30-Jan-99	Administrative Change
DWN ERT Mod 16	Appdx B Rev B	25-Aug-98	4-Sep-97	30-Jan-99	AB04 date change
DWN ERT Mod 17	Appdx F Rev A	28-Aug-98	4-Sep-97	29-Mar-99	AB09, AB10 dates changed
DWN ERT Mod 18	SOW Rev D	10-Sep-98	4-Sep-97	29-Mar-99	ODT move to ARL
DWN ERT Mod 19	Appdx G Rev A	29-Sep-98	4-Sep-97	29-Mar-99	Virtual Planner Mod

2.1.8.1 AUSA Support (SOW Appendix A)

STRICOM was requested to support the AMC exhibit at the October AUSA meeting held in Washington, DC. Specifically, STRICOM was tasked to field an exhibit in the overall AMC corporate exhibit. STRICOM elected to showcase the DWN project and the ADST II program in their allotted space in the AMC exhibit.

Specific objectives included the following:

a) Demonstrate the SVS at the AUSA meeting and at Aberdeen Proving Grounds.

b) Design and produce three (3) electronic posters.

c) Prepare appropriate hand-out materials.

d) Provide SME expertise at the show.

Scenarios were developed for DI SAF at the LWTB by LMTSG personnel. These scenarios were used to provide targets for the SVS, which was connected to the DI SAF via a DIS 2.0.4 Ethernet linkage.

In addition, the electronic form of the posters was developed and hand-out materials prepared. They were reviewed and approved by STRICOM.

The DI SAF and SVS equipment was shipped to and from the AUSA Exhibits Division, Aberdeen Proving Ground (APG), Maryland for rehearsal and installed at the AUSA meeting site in Washington, DC. Technical support from LMTSG personnel stationed at the LWTB was provided at both the rehearsal and the AUSA meeting. A LMTSG SME was also provided to man the booth for the duration of the AUSA meeting.

The following schedule summarizes the major project milestones.

Table 2.1.8.1-1: AUSA Support Schedule

MILESTONE	**DATE**
Contract Award	12 September 1997
DI SAF scenario developed	19 September 1997
Hand-out materials completed	26 September 1997
Ship equipment to AMC	29 September 1997
Set-Up Equipment at AMC	30 September 1997
Rehearsals at AMC	2 October 1997
Support tear-down and packing of equipment at AMC	3 October 1997
Arrive Washington DC	11 October 1997
Support AUSA Show in DC	13-15 October 1997
Support tear-down and packing of equipment in DC	16 October 1997
Ship equipment to LWTB from AMC	20 October 1997
Summary Report	12 December 1997

2.1.8.2 3D Visualization (SOW Appendix B)

STRICOM was requested by the Dismounted Battlespace Battle Lab (DBBL) to implement a 3D visualization capability at the McKenna MOUT site. STRICOM elected to perform this work as a mod to the DWN ERT DO.

Requirements were developed based on a series of meetings with DBBL personnel at Fort Benning. This resulted in a Technical Approach, document number ADST-II-MISC-DWN-9700293E, which was last updated November 7, 1997. A 3D visualization capability was developed for the McKenna MOUT site. It is used to observe live action via instrumentation data that is converted into the necessary format to permit viewing on a 3D-stealth viewer.

Specific project objectives were the following:

a) Select a vendor for the 3D Stealth Viewer and acquire the viewer, plus User Manual.

b) Develop software to convert the instrumentation data.

c) Modify the McKenna MOUT visual database for use with the 3D Stealth Viewer.

d) Integrate and test the conversion software with the 3D Stealth Viewer and OTVIS at the McKenna MOUT Site.

The overall approach is illustrated in Figure 2.1.8.1.2-1, and briefly explained below. A PC based 3D Stealth Viewer was acquired following a competitive selection process. This 3D Stealth Viewer was interfaced to the McKenna MOUT data stream via a DIS Translator which was hosted on an LWTB supplied SGI workstation. The DIS Translator also interfaced to the OTVIS, a TRAC-WSMR developed product such that it could receive either data packets or previously recorded data packets. Finally, database modifications were made to the DWN ERT McKenna MOUT database via use of the ADST II MultiGen system.

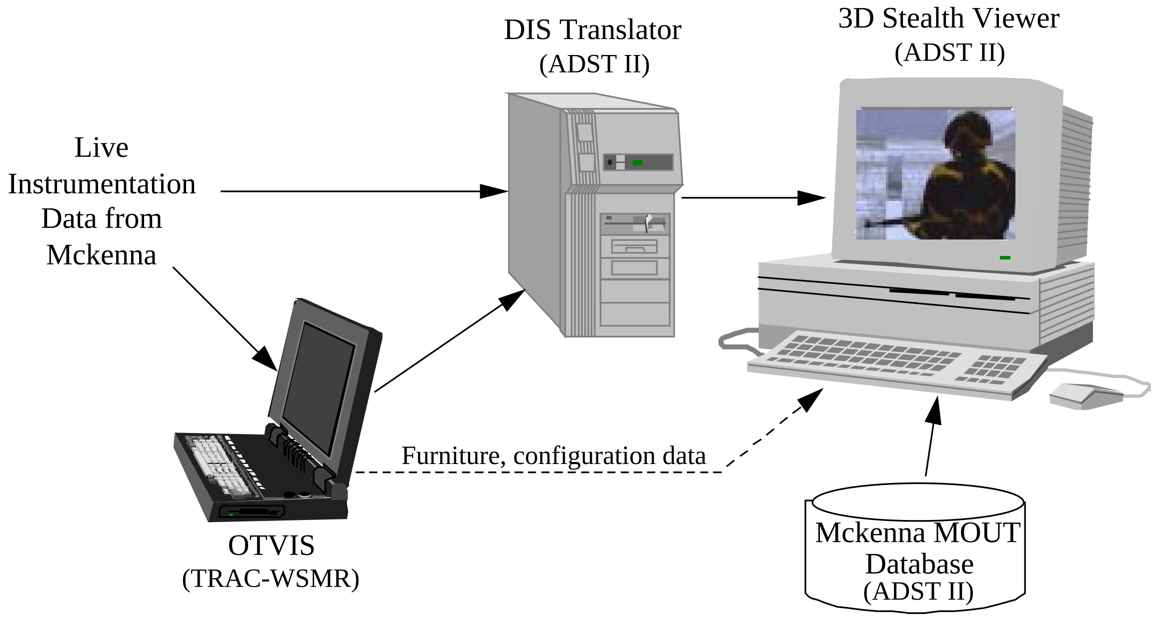


Figure 2.1.8.2-1: 3D Visualization System Diagram

3D Stealth Viewer

We selected the 3D Stealth Viewer produced by RBD for use on this project. Rationale is discussed elsewhere [ref 2.4.2.f].

The 3D Stealth Viewer provided the following capabilities:

a) DIS 2.0.4 compatibility

b) Support for a minimum of two squads (18 soldiers) simultaneously

c) Six uniform types, and M-16, M203, M4, & AK47 weapon models

d) Animation support including running, walking, standing, wounded and killed

e) The ability to "tether" to any of the soldiers

f) Wireframe mode so that the entities may be observed "through the walls"

g) Automatic placement of furniture

h) Combat ID

i) The ability to move freely through the database, inside and outside the buildings, in magic carpet, ground hugging, or DI mimic modes

j) Sensor simulation for NVG and thermal sensors

k) PAQ/4 aiming light simulation

DIS Conversion

A DIS interface was developed to convert the MOUT sensor data into DIS Protocol Data Units (PDUs). This interface software runs on an SGI Indy workstation that was borrowed from existing LWTB inventory. It interfaces with the customer-supplied computer via Ethernet. See Figure 2.1.8.2-2.

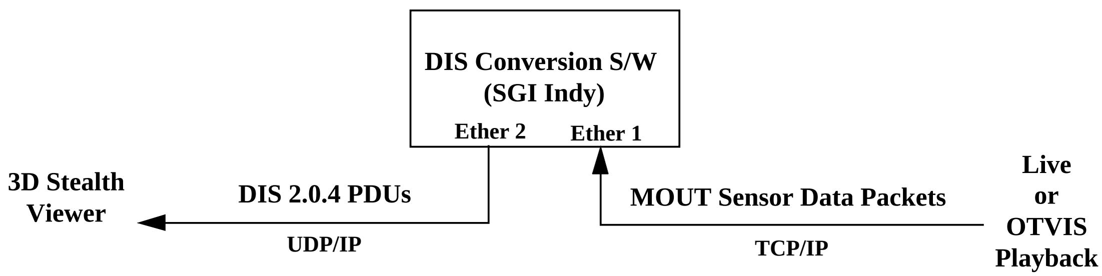


Figure 2.1.8.2-2: DIS Conversion

This DIS conversion software models the soldier posture and action in accordance with the sensor information and in accordance with standard DIS 2.0.4 protocols. Due to the lack of height and direction information in the sensor data stream, soldier posture is assumed to be upright (except for wounded and killed conditions) and soldier orientation is inferred from the most recent position changes.

The DIS Conversion software also creates Fire and Detonation PDUs, which define weapon firing and impacts, respectively. The location of the shooter, the time of fire, and the direction of the round (direction is inferred) are recorded in the Fire PDU. The location of the target, the time of impact, and the identification of the firing weapon (and by inference the shooter) are recorded in the Detonation PDU.

Database Updates

The origins of the McKenna MOUT Database used on DWN ERT were described in paragraph 2.1.3. Under this task, additional changes were made to the database:

a) The interiors of all 15 buildings were modeled, based on drawings and field measurements.

b) A library of furniture models was created corresponding to the models provided with OTVIS. These furniture models can be loaded into the 3D Stealth Viewer at initialization time based on a file created by the OTVIS operator.

c) Sensor characteristics were added to support infrared viewing on the 3D Stealth Viewer. This was accomplished via the use of IRGen, a MultiGen compatible sensor modeling software tool that had recently been acquired by ADST II.

Figure 2.1.8.2-3 is a top-down rendering of the database, with textures disabled.

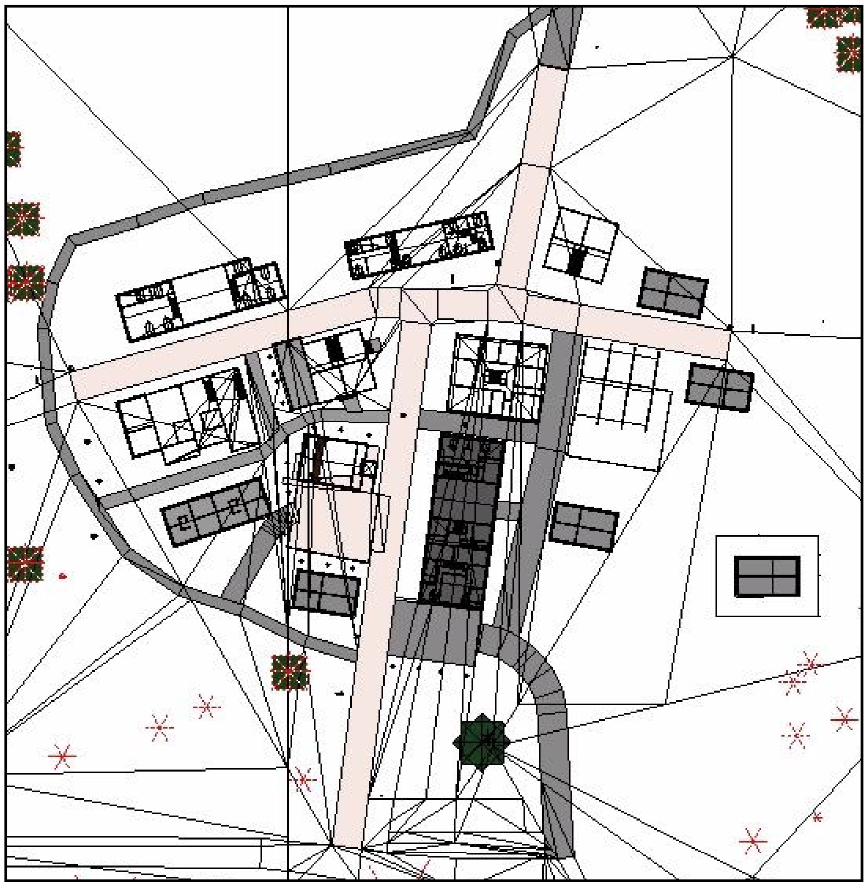


Figure 2.1.8.2-3: McKenna MOUT Database

Work was funded and performed in three phases, in accordance with the milestone schedule shown in Table 2.1.8.2-1. The first two phases established the basic capability just described. Phase 3 tasks, which are underway as of the submission of this report, include the following:

a) Set-Up/Playback Streamlining and Automatic Furniture Placement: this task will reduce the number of keystrokes required to set-up the 3D Stealth Viewer for real-time monitoring or for playback. This includes the reduction of keystrokes required to initialize the 3D Stealth Viewer with a furniture file created previously by OTVIS.

Table 2.1.8.2-1: 3D Visualization Milestone Schedule

MILESTONE	DATE
Phase 1 Award	25 September 1997
Selected 3D Stealth Viewer vendor put on contract	1 October 1997
3D Stealth Viewer delivered to LM	1 December 1997
DIS Conversion Software Completed	1 December 1997
McKenna MOUT database modifications completed	1 December 1997
Subsystem Integration at LWTB	1 Dec. 1997 - 15 Dec. 1997
System Integration at MOUT Site	15 Dec. 1997 - 15 Jan. 1998
System Delivery Phase One	15 March 1998
Phase 2 Award	30 April 1998
Phase 3 Award	25 August 1998
CDRL AB04 submittal	30 Dec. 1998
On Site Support (4 hrs per month via LSE funds)	15 Jan. 1998 - 30 Dec. 1998

a) Teleport using OTVIS Position: this task will allow the user to teleport the eyepoint on the 3D Stealth Viewer based on a position selected via OTVIS. The user selects a position using the mouse on the OTVIS 2D display, and upon selection the 3D Stealth Viewer eyepoint is immediately changed to the selected position.

b) OTVIS Soldier Numbering: this task will result in a 2D overlay on the 3D Stealth Viewer showing the number of the soldier per the OTVIS numbering convention. The overlay will move with the soldier animation. Note that this is not the same as the "3D" numbers that are currently on the chest and back of the soldier animations.

c) Pairing Lines (3D): this task will create a 3 dimensional pairing line connecting the shooter with the impacted target.

d) Update User Manual - this task will result in an Updated User Manual for the 3D Stealth Viewer, reflecting the changes made in tasks a - d above.

The 3D Visualization project will be summarized in CDRL AB04, DWN 3D Visualization for MOUT Summary Report, which will be published following the completion of the work.

2.1.8.3 DI SAF Support (SOW Appendix C)

Military Operations in Urban Terrain (MOUT) require that building interiors be defined for Dismounted Infantry Semi Automated Forces (DI SAF). A graphical editor was therefore developed to create Multiple Elevation Surfaces (MES) data structures from MultiGen Flight databases. In addition, a Plan View Display (PVD) was developed to support presentation of DI moving through buildings to the DI SAF operator. Finally, ModSAF training was acquired to minimize schedule risk for the software development associated with DI SAF.

This task was added when it was discovered that it would not be possible to use an existing McKenna MOUT Site building that had previously been constructed as a MES model using strictly manual methods. It therefore became necessary to create another MES model for the McKenna MOUT Site including the necessary development and visualization tools.

Table 2.1.8.3-1 summarizes the major project milestones.

Table 2.1.8.3-1: DI SAF Support Milestones

MILESTONE	DATE
Modification Contract Award	24 November 1997
Dynamic aperture libCTDB code received from ARL	13 January 1998
MES/DI SAF merged code received from SAIC Burlington	13 January 1998
DI SAF PVD enhancement code received from SAIC Burlington	22 February 1998
Building A MES model received from SAIC Burlington	23 March 1998
MES/DI SAF merged code and DI SAF PVD demonstrated	06 April 1998
MES Editor plug-in code received with documentation	27 April 1998
MES Editor demonstrated	29 April 1998
Summary Report	30 May 1998

See CDRL AB02, DI SAF MOUT Enhancements Final Report, for more detail.

2.1.8.4 ModSAF Baseline & System Enhancements (SOW Appendix D)

This mod provided funding to integrate DI SAF into ModSAF and to make a number of system enhancements necessary to meet DWN ERT experiment requirements.

2.1.8.4.1 ModSAF Baseline

DI SAF V3.0 was integrated into the ModSAF baseline. The following subtasks were performed:

a) Develop and/or update ModSAF Info files to document DI SAF behaviors.

b) Develop and/or update DI SAF/ModSAF documentation; composed of four documents: DI SAF Conceptual Model, DI SAF Software Requirements Specification (SRS), DI SAF Software Design Description (SDD), and DI SAF Software Test Description.

c) ModSAF pre-integration and hand-off to the ModSAF Integration team.

d) Technical and Tactical Assessment of DI SAF software.

See CDRL AB02, DI SAF MOUT Enhancements Final Report, for more information on this ModSAF Baseline task.

2.1.8.4.2 System Enhancements

Some changes to the VICs were required to meet the needs of the DWN ERT experiments. The following subtasks were performed:

a) Integration of SVS with graphics accelerator (Real3D Pro) to yield VIC Delta (described below).

b) Integration of SVS with graphics accelerator (Real3D Pro), Omni Directional Treadmill (ODT), DI C4I subsystem, and Head Mounted Display (Kaiser ProvView 80 HMD) to yield VIC Golf (described below).

c) Upgrade of processors and internal graphics of two existing SVS PCs using the best commercial off the shelf technology available compatible with the existing SVS software (this was done to VIC Delta).

d) Enhancements to standard SVS weapon aiming to support application with the Dome Segment Display System (part of VIC Echo).

e) Incorporation of DI Guy enhancements necessary to support MOUT operations.

f) Upgrade and incorporation of virtual radio sets to support soldier communications.

VIC Delta

A Real 3D Pro Model 1400 was acquired and integrated with the SVS to yield a higher update rate at 800x600 resolution. The integrated VIC Delta system was modified to support operation in two modes: mode 1 utilizes a high resolution (800 by 600) rear projection channel and the IHAS is driven by the SVS PC; mode 2 utilizes a VGA (640 by 480) rear projection channel and the IHAS is driven by the unused channel of the Real3D Pro. Figure 2.1.8.4-1 illustrates.

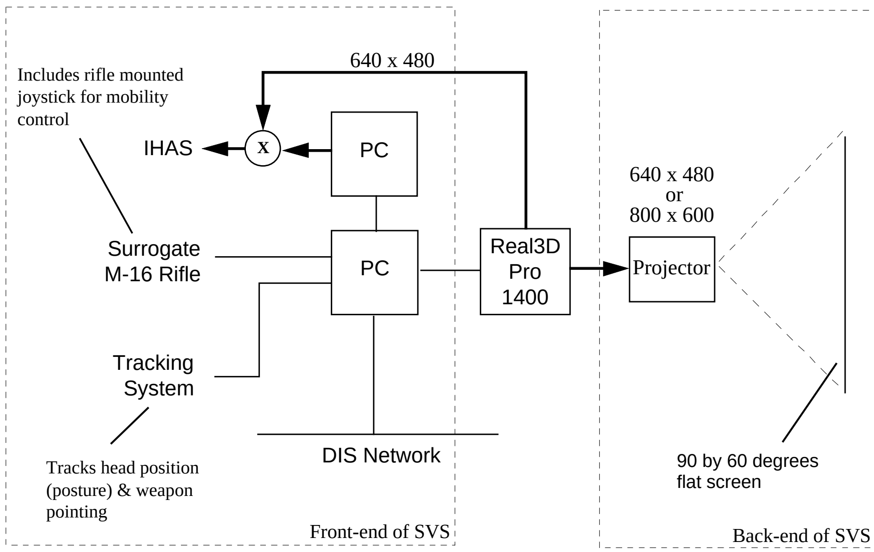


Figure 2.1.8.4-1: VIC Delta Block Diagram

VIC Golf

As with VIC Delta, a Real 3D Pro Model 1400 was acquired and integrated with the SVS to yield a higher update rate at 640 x 480 resolution in dual channel mode. A Kaiser Pro-View 80 HMD was acquired and interfaced to the Real3D Pro. SVS software was modified to support both binocular and stereoscopic viewing modes. Finally, the SVS was interfaced with the Omni-Directional Treadmill. See figure 2.1.8.4-2.

In both display modes the HMD is head coupled such that the Instantaneous FOV (IFOV) corresponds to the direction in which the HMD is pointed. Both modes also support presentation of virtual aiming that represents the direction in which the rifle is pointed.

The integrated system is capable of running with the ODT turned on or off. When the ODT is off, locomotion is controlled by the SVS rifle mounted joystick. Whether on or off, the ODT safety harness is used to prevent injury to the soldier.

A Users Guide describing operation and maintenance of VIC Golf was prepared and delivered to the LWTB for use by site engineers.

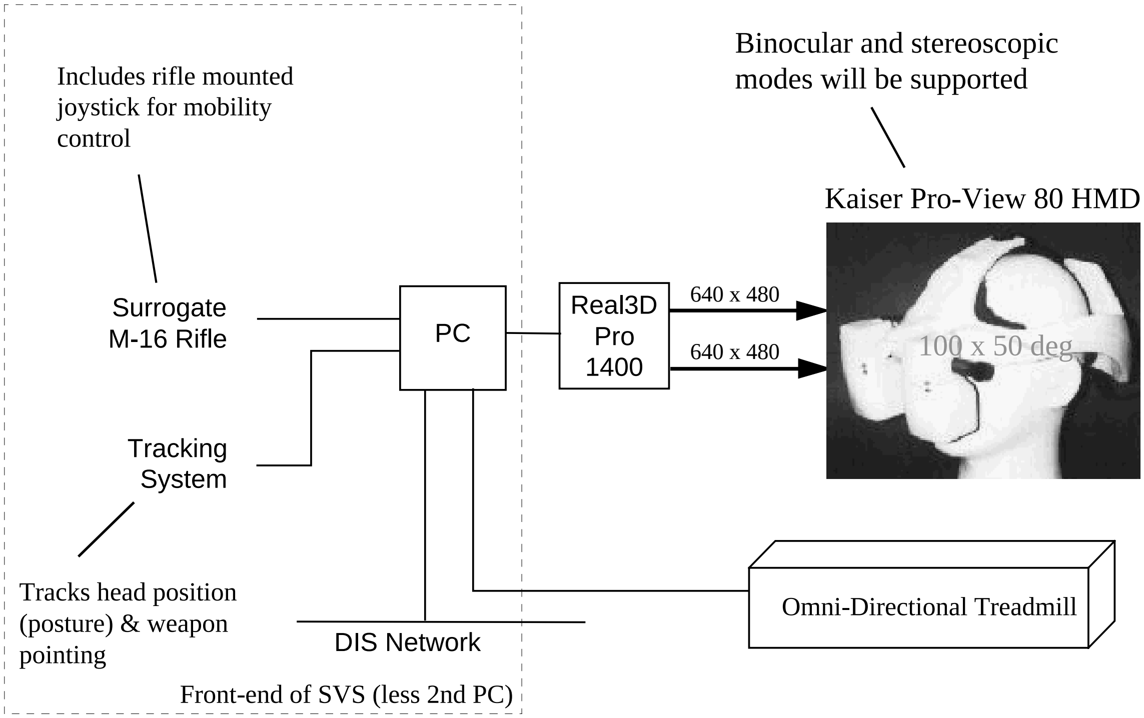


Figure 2.1.8.4-2: VIC Golf Block Diagram

Table 1.2.8.4-1 identifies the major milestones for this effort.

Table 1.2.8.4-1: Task Milestones

MILESTONE	DATE
Modification Contract Award (CA) Date	22 December 1997
Complete System Enhancements	8 July 1998
Hand-off DI SAF 3.0 to ModSAF Integration Team	31 August 1998
CDRL AB06 submittal (ModSAF Baseline documentation)	11 September 1998
CDRL AB07 submittal	30 September 1998

2.1.8.5 STOW-A 160th Special Operations Aviation Regiment (Airborne) Training Exercise (SOW Appendix E)

This task is not directly related to DWN ERT therefore the reader is referred to CDRL AB08, Results of Analysis for STOW-A SOAR(A) Training Exercise, CM # ADST-II-CDRL-DWNERT-9800124.

2.1.8.6 Capstone Study (SOW Appendix F)

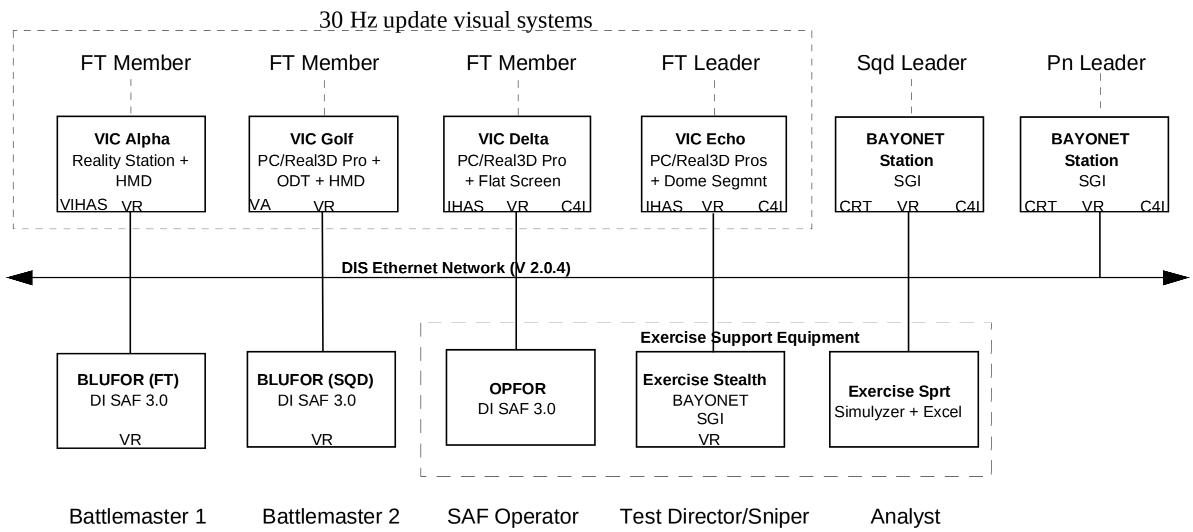
Since this task is still underway as of the submission date of this report, this work will be documented in the Summary report that is due December 30, 1998 (CDRL AB10) and the study report itself (CDRL AB09), also due December 30, 1998.

2.1.8.7 Virtual Planner (SOW Appendix G)

Since this task is still underway as of the submission date of this report, this work will be documented in the Summary report that is due December 30, 1998 (CDRL AB11).

2.2 DWN ERT System Description

The top-level system block diagram for the DWN ERT is shown in Figure 2.2-1. This is the configuration of the system when the DWN user exercises were performed at Fort Benning in July 1998.



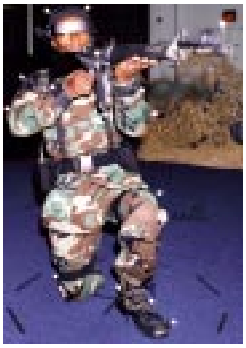
~~Notes:~~
(1) Clearcom intercomm and/or PA system for operator coordination; Clearcom connected together on a separate intercom network ("admin net");
(2) DIS compatible virtual radios used between soldiers using the various VIC's and the SAF Operators; connected together on a separate ethernet network; denoted with "VR" on the diagram. Alpha VR is wireless.
(3) SIM's denoted with "C4I" inlcude DI C4I simulation; "IHAS" denotes LW monocular eyepiece; "CRT" denotes presentation of IHAS data on the CRT; "VIHAS" = IHAS presented on HMD (virtual IHAS); "VA" = virtual aiming

Figure 2.2-1: DWN ERT System Block Diagram

As shown, the system consists of four Virtual Individual Combatant Simulators (VIC), a BLUFOR DI SAF station, Exercise Support equipment, and an After Action Review (AAR) capability. All systems are connected via an Ethernet network and communicate with each other via Distributed Interactive Simulation (DIS) 2.0.4 Protocol Data Units (PDUs). A separate virtual radio network on its own DIS Ethernet LAN supports the system operators (admin net).

VIC Alpha: consists of the Dismounted Soldier System (DSS) with enhancements:

- Developed by Veda under a STRICOM applied research effort
- Video based full body motion tracking
- Rifle mounted joystick for locomotion control
- Biomechanics based human animation model
- Improved Wireless Head Mounted Display
- Weapon Simulation (supplied by NAWCTSD)
- SGI Onyx2 Reality Station Image Generator
- Omni-directional Sound (Soundstorm by RBD)

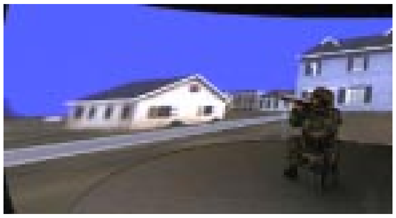


VIC Delta: consists of RBD's Soldier Visualization Station (SVS), a Real3D Pro and a simulated IHAS:

- SVS
  - Developed by RBD, builds on BAYONET software from DWN
  - Intersense hybrid inertial/acoustic motion tracker
  - Two Pentium PC based image generator front-ends
  - Rifle mounted joystick for locomotion control
  - Human animation support (DI Guy by BDI)
  - Simulated Land Warrior rifle
  - Projector and screen
- Real3D Pro and IHAS
  - Dual channel Model 1400 Real3D Pro image generator
  - Screen resolution 640 by 480 or 800 by 600
  - Simulated IHAS made by Kopin; 640 by 480, monochrome

VIC Echo: consists of RBD's Soldier Visualization Station (SVS) less the projector and screen, two Real3D Pros, a simulated IHAS, and a dome segment display:

- SVS
  - Developed by RBD, builds on BAYONET software from DWN
  - Intersense hybrid inertial/acoustic motion tracker
  - Two Pentium PC based image generator front-ends
  - Rifle mounted joystick for locomotion control
  - Human animation support (DI Guy by BDI)
  - Simulated Land Warrior rifle
- Real3D Pro and IHAS
  - Dual channel Model 1400 Real3D Pro image generator, 640 by 480 each channel
  - Single channel Model 1400 Real3D Pro image generator, 1024 by 768
  - Simulated IHAS made by Kopin; 640 by 480, monochrome
- Dome Segment Display
  - On loan from LMIS to the government
  - Provides a 150 degree horizontal by 40 degree vertical field of view
  - Three high resolution Barco projectors included



VIC Golf: comprised of a Soldier Visualization Station (SVS) minus the projector and screen, a Real3D Pro Image Generator driving a Kaiser Pro-View 80 Helmet Mounted Display (HMD), and the Omni-Directional Treadmill (ODT). These subsystems are described below:

- SVS
  - Developed by RBD, builds on BAYONET software product from DWN
  - Intersense hybrid inertial/acoustic motion tracker
  - Two Pentium PC based image generator front-ends
  - Rifle mounted joystick for locomotion control
  - Human animation support (DI Guy by BDI)
  - Simulated Land Warrior rifle

- Real3D Pro and HMD
  - Dual channel Model 1400 Real3D Pro image generator
  - Kaiser Pro-View 80 HMD
  - Two displays, each 640 by 480, monochrome
- ODT
  - Developed by Virtual Space Devices Under STRICOM applied research effort
  - Force feedback response to terrain slope changes

BAYONET Stations:

- Developed by RBD on DWN
- Desktop CRT display plus flybox
- Movement control via joystick
- Weapons aiming via joystick
- SGI Image Generator (Maximum Impact and O2)
- Directional Sound

DI SAF Station: consists of DI SAF software running on an SGI Indy workstation. This station is characterized as follows:

- Under development by SAIC for DWN ERT
- Based on DI SAF developed under DWN
  - DWN version emphasized open terrain operations
  - DWN ERT version emphasizes MOUT operations
- SGI Indy Workstation
  - DI SAF Execution + Plan View Display
  - Animation support provided by BAYONET software with DI Guy on SGI Maximum Impact
- Formal ModSAF Release
  - DI SAF to be incorporated into the Army's official ModSAF baseline in 1999

Exercise Support: A Stealth and a Simulyzer were used to provide experiment support, as described below:

- Stealth

  - SGI Maximum Impact with BAYONET software
  - Permits exercise conductor/facilitator to oversee activities
  - A similarly configured station was also used as a Sniper (OPFOR)
- Simulyzer
  - PDU data logging and real-time monitoring

Table 2.2-1: VIC Simulator Characteristics

DWN Capability	**VIC Alpha** (DSS)	**VIC Delta** (SVS + Real3D + IHAS)	**VIC Echo** (SVS + Real3D + IHAS + Dome Segment)	**VIC Golf** (SVS + Real3D + ODT + HMD)	**BAYONET Stations**
Visual System Description	2 ch Onyx Reality Station, 2 R10000 CPUs; 128 MB	2 PCs with 3Dfx & 256 MB memory + 1 Real 3D Pro	2 PCs with 3Dfx & 256 MB memory, plus 2 Real3D Pros	2 PCs with 3Dfx & 256 MB memory plus 1 Real 3D Pro	1 ch Max Impact, 1 R10000 CPU, 128 MB
Update Rate	20-30 Hz	15-30 Hz	15-30 Hz	15-30 Hz	5 - 10 Hz
3D Display characteristics (color, pixels/lines, FOV)	1 ch wireless HMD 789 by 230 NTSC Color 45 deg FOV 360 deg FOR	1 ch screen 640 by 480, 800 x 600 Color 90 deg FOV 360 deg FOR	3 ch dome segment 1024x768 ctr 640x480 sides Color 150 deg FOV 360 deg FOR	2 ch HMD 640 by 480 ea Binocular or Stereoscopic Color 100 deg FOV 360 deg FOR	1 ch CRT 1280 by 1024 Color 45 deg FOV 360 deg FOR
Horizontal Resolution (arc-min/pix)	3.4	8.4	2.9/4.7	4.7	2.1
IHAS Display	option in HMD	yes (mono, 30 deg FOV, 640 by 480)	yes (mono, 30 deg FOV, 640 by 480)	option in HMD	no
DI C4I Simulation	no	yes	yes	no	yes
Virtual Radio	yes	yes	yes	yes	yes
Locomotion	thumbswitch on rifle	thumbswitch on rifle	thumbswitch on rifle	thumbswitch on rifle or ODT	joystick on desktop
Local Animation Capabilities/Limitations	Biomechanics DI Model	DI Guy	DI Guy	DI Guy	DI Guy
Aural cues - mono/stereo, omni-directional	omni-directional	stereo	stereo	stereo	stereo
Weapon Tracking	video	inertial + acoustic	inertial + acoustic	inertial + acoustic	joystick
Dynamic Terrain (holes in walls, breaching)	yes	yes	yes	yes	yes

<u>After Action Review Support Equipment:</u> During the user exercises, BAYONET hosted on a Maximum Impact served as a stealth display for After Action Review (AAR). Simulyzer played back PDUs recorded during the previous exercise and transmitted the PDUs to the AAR Stealth.

The performance of the various VICs is tabulated in Table 2.2-1. Figure 2.2-2 depicts the DWN ERT communications systems.

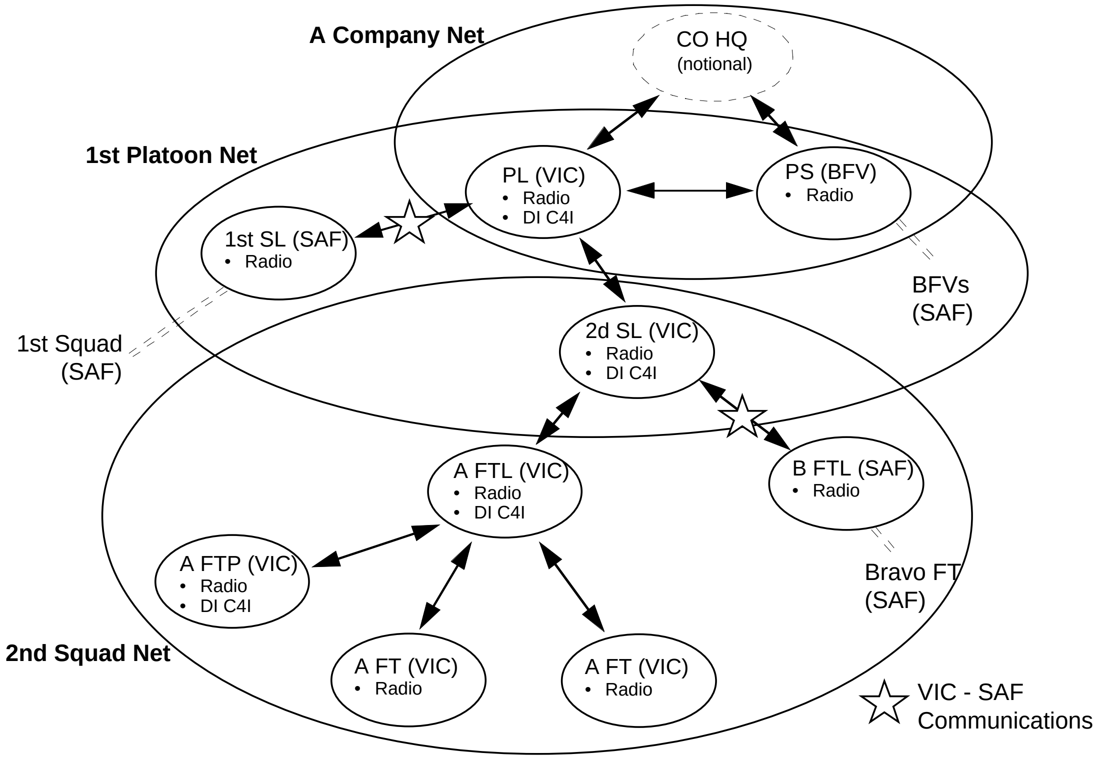


Figure 2.2-2: DWN ERT Communication Systems

3.0 DWN System Integration and Demonstration

3.1 Technical Interchange Meetings (TIMs)

Two formal TIMs were held at LMIS on 19 November 1997 and 28 January 1998, with informal working group meetings held the day before each TIM. The first TIM reviewed the DWN ERT program effort to date. The overall system design concept was discussed, and a member of each of the VIC development teams presented an overview and capabilities assessment of their system. DI SAF development status was also presented. Dynamic terrain implementation plans and issues were discussed. Preliminary plans for the engineering experiments and user exercises were presented and discussed. The meeting concluded with presentations on programs and activities that could benefit from DWN-related development efforts. These included MOUT Advanced Concept Technology Demonstration (ACTD), Objective Individual Combat Weapon (OICW), Close Combat Tactical Trainer Dismounted Infantry Module, TRAC-WSMR's OTVIS (Operational Test Visualization), and MOUT Instrumentation System.

The second TIM updated the overall project and individual subsystem development status, including DI SAF and Boston Dynamic's DI Guy. The experiment plans were presented and discussed, and general agreement obtained by the participants. STRICOM's safety representative presented system safety certification requirements. Guest presentations were made by individuals from the Institute for Defense Analysis (IDA) and Los Alamos National Laboratories.

Representatives from the following organizations participated in one or both of the TIMs: LMIS, RBD, Veda (now Veridian), TRAC-WSMR, NAWCTSD, LMTSG, IDA, STRICOM, NVESD, PM-Soldier, ARI, TSM Soldier, Mitre, Natick RD&E, SAIC, BDI, ARL, USAIS, DBBL, Sandia National Labs, Soft Reality, Real3D, DOT, Raytheon, TRAC-MTRY, Omega Training, and Seamless Solutions.

As mentioned, working group meetings with the development and integration team were held prior to each of the TIMs. During these meetings, consensus was reached on a number of issues including PDU enumeration values, dynamic terrain implementations, markings for the animated soldiers, and other issues. Notes summarizing the agreements reached during these meetings are reproduced below.

3.1.1 Dynamic Terrain

<u>Hole Creation:</u>

a) The AT8 will be the weapon used to create holes in wall. A large building hit result in the detonation PDU will trigger hole creation.

b) A 2-meter diameter hole will be created. ARL has provided code with operational size parameter.

c) SAF hole will be a rectangle as currently implemented; the VICs' hole will be circular.

d) A one-meter (± 1/2 meter) vector along the warhead flight path will be used to determine wall thickness/impact.

e) There will be no indirect fire effects on live entities as a result of AT8 warhead detonations.

f) The hole created by the AT8 will be flush with the floor inside Room 1 of Building A. This will be slightly above the level of the terrain just outside of this room.

g) The VIC must be able to handle (traverse) a step of 1/2 meter.

h) To handle weapon changes, the primary weapons for a fireteam will be AT8, SAW, and M-16. The secondary weapon for the AT8 entity will be the M-16. After the AT8 is fired, the primary weapon will be set to zero and the secondary weapon will be deployed when needed.

Door/Window Breaching:

a) The SAW will be the weapon used to breach doors and windows. A medium building hit result in the detonation PDU will trigger door and window removal. The M-16 will produce small building hit results that will have no dynamic terrain effect.

b) A 20-centimeter (± 10 cm) vector along bullet flight path will be used to determine door/window thickness/impact.

c) Door and window models will be embedded in the building models.

d) At least one window will be modeled to demonstrate window breaching. Three doors will be modeled: one between rooms 1 and 3, one between rooms 11 and 12, and one between rooms 11 and 13.

3.1.2 Dismounted Infantry Model

a) Friendly forces will wear green BDUs; OPFOR will wear dark green uniforms.

b) Postures supported will consist of upright standing/walking/running, kneeling, prone/crawling, and crouching. Veda will have to add crouching.

c) The new DI Guy "Quick Kill" postures will be used for all DWN ERT experiments, replacing the existing DI Guy deployed and firing position postures.

d) The question was raised whether the VIC with an IHAS simulation should be portrayed using the Land Warrior-equipped model of DI Guy. This would contradict the uniform decision made previously (see 'a' above). It was decided to use the standard non-LW model.

e) Individual DI entities will be discriminable based on a 3-character identifying code to be placed on the front and back of each DI model. These codes will be contained within the marking field in the Entity State PDU. The codes used will be based on the following table:

Platoon Leader: **1PL**
Platoon Sergeant: **1PS**
Fireteam (FT) as follows:

	1st Squad - Leader = **1SL**				2nd Squad - Leader = **2SL**			
	M16	M16	M16[2]	M249	M16	M16	M16[2]	M249
Alpha FT	**1A1**	**1A2**	**1A3**	**1A4**	**2A1**	**2A2**	**2A3**	**2A4**
Bravo FT	**1B1**	**1B2**	**1B3**	**1B4**	**2B1**	**2B2**	**2B3**	**2B4**

Notes: 1) Codes are in bold type
2) Third fireteam member is the fireteam leader
3) BDI will modify DI Guy to accept these identifiers, which will be specified in the Entity Marking field in the entity state PDU.

3.1.3 PDU Enumerations

a) LMIS presented an initial listing of enumerations to be used for Entity State, collision, fire, and detonation PDUs. These were modified during Pre-TIM #2 and were revised and re-distributed.

3.1.4 Model Parameter Definitions

a) LMIS distributed a copy of parameters to be used by the VICs and SAF to specify human heights (and eye heights), posture transition times, and movement rates. This was modified and will be revised and re-distributed. *(Note: See results in Section 3.2 below.)*

3.1.5 Radio Networks Model Definition

a) Squad and platoon radio nets were described and radio assets were allocated to the VICs and supporting stations. ASTi radio interfaces will be provided to the four VIC, the Squad Leader, two Battlemasters (SAF squad and fireteam leaders), and the Platoon Leader. The Test Director will monitor both nets, and an additional speaker will broadcast both nets to a demo viewing area. The BFV and SUTT will not be provided with ASTi links, although SUTT will determine during integration if its radio is compatible with the ASTi. *(Note: SUTT did not participate in DWN ERT.)*

3.1.6 LWTB Equipment Layout

a) The preliminary LWTB equipment layout and hardware requirements/allocations were presented and discussed. No issues were identified.

3.1.7 LWTB Integration Schedule

a) RBD will begin integration of VIC Echo and Golf at the LWTB on February 16th. Veda will arrive on the 23rd to begin assembly of VIC Alpha. The SUTT will also be ready to be assembled beginning on the 23rd. *(Note: SUTT did not participate in DWN ERT.)*

3.1.8 Miscellaneous

a) Discussed maintaining unity gain in the VIC' visual systems. RBD work statement does not match FOVs of VIC' display systems. LMIS took action to give RBD FOV requirements for VIC's Delta, Echo, and Golf.

b) RBD said they perceived a need for a shield or visor for the Kaiser HMD to block the wearer's view around the displays. Kaiser should provide this shield to RBD by 2/2/98. *(Note: Shield was received prior to experiments, although it was not used.)*

c) Radio audio will be provided to VIC Golf by a standard headset since audio option for HMD was not purchased.

d) The new DI Guy "Quick Kill" posture discussed in the Dismounted Infantry Model section was intended to provide a quick-response weapon employment mechanism to support movement and fire inside of buildings. When stationary, the weapon is held up across the chest in a ready position. When moving, the weapon is raised to the shoulder and pointed in the direction of travel. If an enemy is encountered the weapon can be pointed and fired quickly. The group determined that this would be the appropriate posture for building clearing operations.

3.2 Simulation Model Parameters

During the first pre-TIM meeting, it was noted that for interoperability, certain parameter values that the simulators use for such things as speeds for gait transitions and time for posture changes should be collected and made common where feasible. For the DI SAF, parameters such as eye heights at the different postures would effect target acquisition results, and these values were undefined (or arbitrarily defined) in the existing models. Following this discussion, LMIS engineering assembled a questionnaire that was distributed to the VIC and DI SAF development teams which requested information on any human performance characteristics data values used within their simulations. This questionnaire is shown in Figure 3.2-1. LMIS engineering also reviewed relevant literature to determine appropriate values for some required human performance data.

The responses received from the questionnaire are presented in Appendix A. Based on these responses and a review of relevant human performance data, a table was constructed in an attempt to equate a few of these parameter values among the VICs and especially between the VICs and the DI SAF. This table is reproduced as Table 3.2-1. Additional information on efforts to coordinate representations of human characteristics in DWN ERT can be found in the paper by Reece and Dumanoir cited in Section 1.4.2.

Table 3.2-1. Model Parameter Table

Posture Eye Heights (in Inches) and Ratios to Standing Height

Measure[1]	5th Percentile Height	5th Percentile Ratio	95th Percentile Height	95th Percentile Ratio	**Recommended Ratio**
Standing Height	64.8 (1.65 m)	--	73.7 (1.87 m)	--	--
Standing Eye Height	60.2	0.929	68.6	0.931	**0.930**
Crouching Height	49.4	--	59.0	--	--
Crouching Eye Height (est[2])	44.8	0.691	53.9	0.731	**0.711**
Kneeling Height	48.0	--	53.9	--	--
Kneeling Eye Height (est[2])	43.4	0.670	48.8	0.662	**0.666**
Prone Height (ground to top of head while looking forward)	12.3	--	16.4	--	--
Prone Eye Height (est[2])	7.7	0.119	11.3	0.153	**0.136**

Note 1: Standing, crouching, and kneeling data from MIL-STD-1472D; prone data from AFSC DH 1-3

Note 2: Estimated using standing height/eye height differences and applying to kneeling/crouching/prone height data

Posture Transition Times (Seconds)*

From/To	Standing	Crouching	Kneeling	Prone
Standing	--	*0.5*	2.0	5.0
Crouching	*0.5*	--	*2.0*	*4.5*
Kneeling	1.8	*1.5*	--	5.0
Prone	4.5	*4.0*	4.5	--

* All data except crouching from BDI data

Movement Rates

Gait Transition Speeds (Meters per Second)

Standing to walking: Noise value	
Walking to running: 2.0 m/s	
Nominal Speeds for Movement	
Walking: 0.67 m/s	Walking Laterally: 0.35 m/s (*guess*)
Running: 1.87 m/s	
Maximum Sustained Speeds	
Crawling	0.38 m/s (BDI & RBD)
Crouched Walk	0.50 m/s (BDI & RBD)
Walking Backward	-0.45 m/s (BDI & RBD)
Max running (sustained)	3.6 m/s
Max running (sprint) - time limit?	Growth

Human (Dismounted Infantry) Models

1. Vision
    a. Detection/acquisition model - Field of view, range effects, environmental effects, eye height
2. Hearing
    a. Modeled for SAF? If so, parameters of model.
    b. Presentation to user: directional (stereo) or spatial (3-D)
    c. Sounds to be generated (e.g., walking?)
3. Other senses modeled?
4. Movement/locomotion:
    a. Walking, running, crawling
        i. Default speeds
        ii. Speeds effected by terrain slope, soil type, etc.?
        iii. Ford streams and other shallow water terrain?
    b. Other behaviors such as rolling, climbing that support surmounting obstacles?
    c. Able to look in a direction different than the one moving in (while moving)?
    d. Collision testing: bounding volumes, variable depending on posture or extending limbs, e.g., arms?
5. Postures: Standing, kneeling, prone, crouching, . . .
6. Gestures: List gestures supported (generation VICs and SAF, recognition SAF)
    a. VIC generation: continuous user movement tracking or canned motion?
7. Hit damage assessment: wound/kill models or algorithms

Sensor Models

1. Types supported:
    a. Passive: NVG (I^2), IR, optical
    b. Active: Laser, IR aiming dot, lights
2. Dynamic field of view adjustment?
3. Resolution adjustments?
4. Impact on target acquisition models?
5. Combat identification simulation?

Weapon Models

1. Weapon types supported
2. Ballistic model(s): effective ranges
3. Munitions types and effects
4. Sensors associated with weapons for sighting/aiming (scopes, IR aiming dots, etc.)

Display

1. Differential display of entities based on detection/recognition status?
2. Level of detail for models; range filters; dynamic LOD, e.g., for animation of DI models.

Figure 3.2-1. Human Performance Data Questionnaire

3.3 Integration and Demonstrations at Fort Benning

The initial DWN ERT plan was for integration to begin at the LWTB at Ft. Benning on 2 March 1998 and to be completed in time for the engineering experiments to begin on 16 March. However, due to a scheduling difficulty, soldiers were not available during this period. Subsequent resolution of soldier availability resulted in the experiments being rescheduled to the two weeks of 13 through 24 July, with training and final integration occurring the week prior to this (6 – 10 July).

Initially, it was anticipated that integration would simply be postponed until July, thus affording VIC and DI SAF developers more development time, which would benefit both VICs (except for Alpha) and DI SAF performance. However, certain events had been scheduled based on the March availability – the system safety inspection was scheduled for March 4th, and a system demonstration in support of a briefing to potential MOUT ACTD and OICW customers had been scheduled for March 12. Additionally, a Blue Ribbon panel convened to assess testbed capabilities to support funding decisions was scheduled to visit the LWTB on April 6. Thus, an operational system was required within this initial time period. Therefore, two integration efforts were undertaken, the first in March culminating in system demonstrations in March and April, and a second in July, which also culminated in a demonstration as well as in the rescheduled engineering and user experiments.

3.3.1 Initial Integration and Demonstration

The layout for all of the integration efforts and subsequent demonstrations and experiments is shown in Figure 3.3-1. This layout was developed by LWTB personnel and was reviewed and approved by the DWN team. It provides ample room for all the VICs and good oversight positions for the test team. It isolates VIC Golf, with its noisy ODT, so that it doesn't present an operational or safety problem to other personnel not associated with its operation.

Prior to the July integration that culminated in the experiments, there were two development/integration efforts that were conducted in support of system demonstrations. The first was over the period of March 2 – 12, 1998. This was an intense effort to provide basic system capability in the face of substantial technical challenges in getting the SVS-based systems (Delta, Echo, Golf) to run adequately with the Real 3D Pro image generators, and also to achieve an adequate weapon aiming solution. DI SAF operations inside of buildings were also problematic during this period. Despite these challenges, the DWN team put forth a concerted effort and managed to provide the required functionality for the demonstrations to potential OICW and MOUT ACTD customers on March 12th.

The second demonstration was conducted on April 6th, with a supporting integration effort beginning on March 30th. This demonstration was important to the LWTB as it was being conducted by a DoD Blue Ribbon panel convened to assess the capabilities of all major military test facilities. This assessment would support funding decisions for these

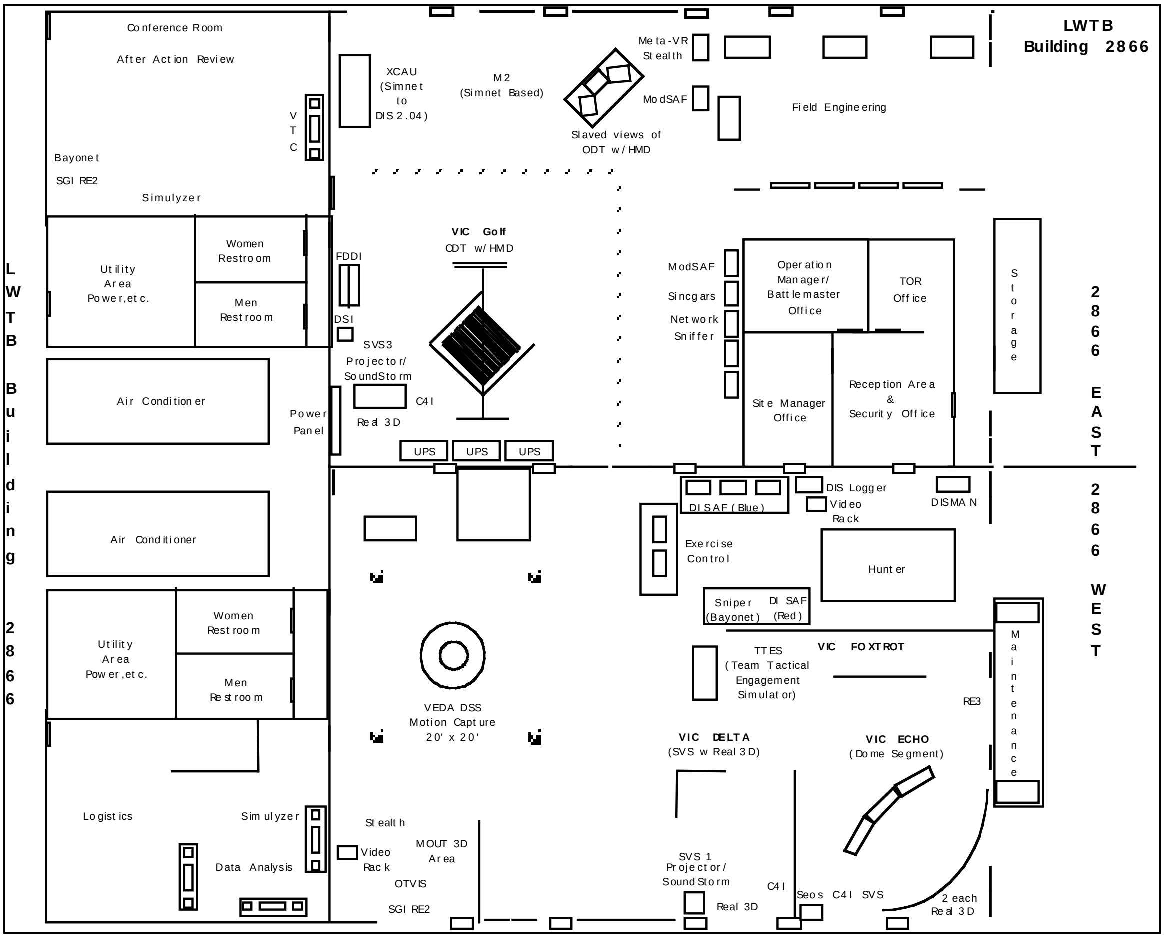


Figure 3.3-1. DWN ERT Facility Layout at the LWTB

testbeds. A comprehensive demonstration of system capabilities was conducted including dynamic terrain, squad-level MOUT operations with integrated VIC and DI SAF units, and automated C4I messaging. Again, DWN system functionally supported the demonstration objectives.

3.3.2 Final Integration and Demonstration

From April to July 1998, VIC and DI SAF development efforts continued to enhance existing system capabilities and to eliminate work-arounds that had been implemented to support the demonstrations. The DWN team reconvened at the LWTB during the week of July 6 to integrate the changes that had been made. Also, another system demonstration was required on July 10 in support of a visit by Newt Gingrich to Fort Benning. The soldiers that were to serve as subjects for the experiments were trained on the systems during this week as they rehearsed for the demonstration. The DWN team again proved their capability to press ahead with development and integration activities while simultaneously supporting demonstration rehearsal and conduct. Again, the DWN system met the required demonstration capability.

It is a credit to the DWN team that reasonable system performance was achieved for the experiments given the distributed, piece-meal integration conducted against a background of soldier training, mission rehearsal, and relatively high-profile demonstrations.

4.0 Engineering Experiments

4.1 Introduction

As a follow-on and extension of the original DWN, the planning process for the DWN ERT effort was basically to follow the format employed during DWN. Both the engineering experiments and user exercises provided valuable data on both the utility of specific existing simulators to support dismounted infantry operations and the requirements in general for such simulators. Given this past success, it was decided to replicate the process but tailor it in consideration of the unique capabilities of the new and modified simulators and of the more specific focus on MOUT operations.

One major difference between the DWN and DWN ERT experiments was the time allocated for their conduct. The original DWN experiments took place over three weeks for each of the engineering and user tests. DWN ERT allocated one week each for engineering and user experiments. This abbreviated test period limited the number of test conditions that could be performed relative to the DWN engineering tests. Also, the DWN integration and engineering tests took place at the LMIS Lake Underhill Road facility in Orlando, while all DWN ERT activities occurred at the LWTB at Ft. Benning. This was because most of the VICs either were located at the LWTB or were to be transferred to the LWTB during the DWN ERT execution period.

The engineering experiments took place during the week of July 13 – 17 and were supported by personnel from RBD, Veridian, LMIS, LMTSG, SAIC, and other site personnel. Nine soldiers from Ft. Benning participated as subjects. The same soldiers (by and large) participated in both engineering and user tests.

This section of the report summarizes the purpose of the engineering tests (4.2) and the experiment planning process and final plan (4.3), details the experiment procedures and results (4.4 and 4.5), and provides discussion and additional interpretation of the results (4.6).

4.2 Purpose

As with the original DWN, DWN ERT was undertaken to investigate requirements for both manned and unmanned simulators needed to support the integration of the individual soldier into the virtual battlefield. The primary rationale for such simulators is presumed to be in support of Advanced Concepts & Requirements/Research, Development & Acquisition (ACR/RDA) activities, with applications to new equipment training (NET) for advanced soldier systems. Again, the emphasis is on proof-of-concept and technology demonstration, not product development.

The core of the DWN ERT system was built from existing LWTB assets. Three SVS simulators had been procured under separate efforts, and Veridian's DSS was due to be transitioned to the LWTB during the DWN ERT period of performance. DWN ERT was responsible for modifying the three SVS systems in order to provide differences among them so as to present opportunities for comparison. All SVS systems were equipped with Real 3D Pro image generators to help overcome the limited update rates (less than 10 Hz) exhibited by the basic PC-based graphics when operating in the MOUT database. Differences among these simulators were generated by replacing the standard single-projector display system of one SVS with a wide-screen three channel projection system capable of high resolution (780 x 1024) in the center channel. A second SVS was modified to operate with the ODT and a head-mounted display. The third SVS was unmodified with the exception of the addition of the Real 3D Pro. DWN ERT also provided funding for the addition of dynamic terrain to the SVS systems. Most of these modifications were the result of the desire to focus on MOUT operations for this phase of DWN. DWN ERT was also responsible for addition of the inside building capability to the DI SAF.

The goal of the engineering experiments was to assess how well the simulators allowed soldiers to move through the environment, both inside and outside of buildings, to acquire targets, and to engage man-sized targets with their simulated weapons. To this end, a series of planning meetings was held to discuss tasks and performance measures. The result of these meetings is discussed in the next section.

4.3 Experiment Plan Overview

Several experiment planning meetings were held with representatives from LMIS, STRICOM, ARI, and SAIC. SMEs from these and other organizations also participated in the planning process either at these or other meetings, such as TIM and pre-TIM meetings. These meetings resulted in the definition of a set of experimental tasks and measures of performance (MOP) for both the engineering and user experiments. These and other aspects of the experiments were documented in the DWN ERT Experiment Plan, which is included in this report as Appendix B. This version of the plan has been updated to reflect as accurately as possible what happened during the execution of the experiments. Since the complete plan is included, it will only be briefly summarized in this section. It will also be noted here where plan execution significantly changed from the original pre-experiment plan. One such case is that the engineering measurements outlined in Section 4.2 of the Experiment Plan were not collected.

As previously stated, the goals of the engineering experiments were to evaluate the VICs support soldier tasks involving moving through and around buildings, detecting and acquiring man-sized targets, again both inside and outside of buildings, and effectively engaging these targets with the systems’ simulated weapons. To this end, three general classes of tasks were identified, with a total of four specific sets of trials defined. These are summarized below.

4.3.1 Locomotion Experiments

The basic purpose of the locomotion experiments was to determine how well the VIC mobility component, in conjunction with the visual system, allows navigation through the virtual environment. This was assessed by requiring the subjects to navigate through Building A within the McKenna MOUT database. One route was defined through the southernmost townhouses in Building A. The soldier traversed this course alternatively in either direction.

The courses were not difficult to learn but required frequent changes in direction, changes in movement speed, going up and down stairs, and movement through confined areas, such as going through doors and hallways. Soldiers were instructed to complete the course as quickly as possible but not at the cost of moving so quickly as to increase the number of collisions with building structure or other objects. MOPs were time to complete the course and number of collisions incurred during its execution.

The original plan had each soldier completing eight locomotion trials on each of the four VICs for a total of 32 trials. It quickly became apparent that this was grossly in excess of what could be completed in the time allotted. Ultimately, each soldier completed nine iterations of the locomotion course.

Also, it was planned that each soldier would alternate one locomotion trial with another trial to complete one 30-minute session. It was determined that since this involved switching databases (McKenna for the targeting "dish" database to be described later), it would take VIC Echo too long to complete this switch. Echo, with its unique projection system, required that the projectors be turned off (put in standby) before the simulation could be shut down, which was required to change databases. The process of bringing down the projectors and then bringing them back up took at least 10 minutes. Given this, the schedule was modified so that both subject sessions (the two tasks completed on a given simulator within each half-hour period) were performed on the same database, i.e., two locomotion trials (routes A & B) were performed back-to-back.

4.3.2 Target Search and Engagement Experiments

These experiments were conducted to assess how well the VIC visual and weapon system components allowed the search for and the detection and acquisition of DI targets in the virtual environment. The visual system component assessed how well the VIC visual systems support the scanning for and detection of DI-sized targets at ranges out to 150 meters. The weapon-aiming component was conducted to assess how well the VIC weapon tracking and visual system components allowed the acquisition and engagement of objects in the virtual environment. This was assessed by requiring the subjects to locate, track, and shoot at static and moving targets.

Two tasks were performed to assess how well the VICs allowed users to locate and engage DI targets. The first focused primarily on the visual and weapon systems; the second included the locomotion subsystem as well.

4.3.2.1 Visual Search and Engagements

Individual participants standing in a fixed position attempted to locate DI targets and engage them with their weapons. A specially constructed dish-shaped database was used for these trials. The flat portion of the dish has a radius of 200 meters for target placement. Targets were presented anywhere within the forward 270-degree field of regard (±135°). Both stationary and moving targets were included.

A total of 48 trials were conducted for presentation of the stimuli for this task: 1 target class (infantry) x 4 distances (25, 50, 100, 150 meters) x 3 speeds (0, 4, 8 mph) x 4 azimuths (230°, 315°, 80°, 130°). A full factorial combination of these values was used to generate the 48 trial conditions.

The original intent was to replicate the ranges used during the Record Fire task that the soldiers would be familiar with. This task is used to measure soldier marksmanship. The ranges used for this task are 50, 100, 150, 200, 250, and 300 meters. Prior to trial definition, it became clear that the aiming solution for the SVS systems could not support target engagement beyond 200 meters. Thus, the range limit was set at 200 meters. During integration, it was obvious that on the basic SVS using the Real 3D Pro, a DI target beyond 150 meters could not seen at all. Thus, the range limit was set at 150 meters, and an additional range value of 25 meters was substituted for the 200-meter range. Thus, the ranges used for the trials conducted were 25, 50, 100, and 150 meters, as indicated above.

4.3.2.2 Locomotion, Search, and Engagement

In this task, the subjects moved through the environment looking for DI targets. Once located, they were fired upon as a recordable signal that they have been located. Two search environments were used: 1) Inside of Building A of the McKenna database, and 2) Along the streets of the McKenna database. The first environment was expected to encourage fast side-to-side scanning for targets at close ranges (inside rooms); the second was thought to involve more vertical scanning as well, since targets were placed at windows on the second and third floors of buildings as well as on rooftops.

The basic task was for the soldiers to follow a defined course (or to search the entire building) and look for DI targets. These targets were stationary and non-reactive. Exact numbers and locations of targets varied from trial to trial to eliminate learning of target locations.

4.3.3 Weapon Aiming Posture Experiment

The weapon aiming experiments were conducted to assess how well the VIC weapon tracking and visual system components allow the acquisition and engagement of DI targets in the virtual environment from standing, kneeling, and prone postures.

The ranges for the previous engagement task were used for this task as well, although all targets were stationary and appeared within the soldier's initial field of view, i.e., within ±25° of the initial line of sight. All targets were engaged from the kneeling, standing, and prone positions. Forty-eight (48) trials were generated for this task: 3 postures x 4 ranges x 4 azimuths (345°, 355°, 10°, 20°) x 1 speed (0 mph) = 48 targets, 16 per posture.

For all trials requiring the generation of dismounted infantry targets, target generation software developed for DWN ERT was used. In DWN, ModSAF was used to generate individual targets. This proved cumbersome, time consuming, and operator-intensive. This new software allows the duration, quantity, motion, inter-trial interval, exercise number, speed, heading, starting and ending locations of targets to be specified. This proved to be a valuable addition to the experimental tool suite.

During the weapon aiming tasks, the plan called for unaided "iron sight" aiming, that is, not using the IHAS sighting implemented by all VICs. The intent was to assess the aiming technology employed by the VIC, although all of the SVS-based VICs (Delta, Echo, and Golf) used the Intersense inertial-acoustic system. During execution of the task, it became obvious that the iron sight aiming was not working. Target hits were infrequent, and soldier motivation was flagging.

They were becoming discouraged and were losing interest in even attempting to perform the task seriously. The decision was made to execute the first half of the aiming sessions with the open sights, then switch to the IHAS aiming for the remaining one-half sessions. Soldiers were asked to bear with the sighting during the first half, to try as best they could, with the promise that performance would improve with the IHAS.

4.3.4 Data Collection

All data collection runs were logged using Simulyzer software. Specific PDU data was parsed from this binary logger file using software developed by LWTB personnel. Entity State, Fire, Detonation, and Collision PDUs were the primary data of interest. Collision data was analyzed for locomotion trials only. PDU data elements extracted to support the analysis is shown in Table 4.3.4-1.

It should be noted that time, as indicated in the PDU headers, was not logged *per se*. No attempt was made to coordinate time stamping among the VIC. Instead, the time stamp automatically recorded by Simulyzer along with each PDU was used as the system time to record when events (PDUs) occurred.

4.4 Experiment Procedures

The experiment was conducted in accordance with the revised experiment plan included as Appendix B. LMIS, STRICOM, TECOM, and LWTB personnel conducted a safety inspection of the VICs and LWTB facility on March 4th. All identified issues were addressed and a safety release was obtained from TECOM prior to soldier participation in the experiments. As during DWN, the only significant issue was the noise generated by the ODT.

4.4.1 Soldier Participants

Eight MOS 11M Fighting Vehicle Infantryman participated as subjects for the experiments (plus one Sgt officer in charge). All were from D Company, 1st Battalion, 15th Infantry Regiment, 3rd Brigade, 3rd Infantry Division (Mechanized) at Fort Benning. (aka Kelly Hill). There were 1 CPL, 3 SPCs, 2 PFCs, and 2 PV2s representing all three platoons within D Co. Their age range was 20-25 years; time in service - 5 years 11 months to 9 months. During the engineering experiments, one soldier ceased participation and was replaced by another in the same ordinal position (see Section 4.4.4). Also, there were occasions due to both anticipated and unforeseen events that a soldier's place in the rotation was taken by a replacement for a session. Obviously, this is undesirable from an experimental perspective and was limited to those occasions where no alternative was available other than not collecting the data. The expected effect of such changes is to increase variability, making it harder to obtain reliable, statistically significant experimental results.

PDU	Data	Fields
Entity State	PDU Header	Exercise ID
		PDU Type
		Time Stamp
	Entity ID	Application
		Entity
	Entity Type	Entity Kind
	Entity Linear Velocity	X Component
		Y Component
		Z Component
	Entity Location	X Component
		Y Component
		Z Component
	Entity Orientation	Psi
		Theta
		Phi
Fire	PDU Header	Exercise ID
		PDU Type
		Time Stamp
	Firing Entity ID	Application
		Entity
	Target Entity ID	Application
		Entity
	Location in World	X Coordinate
		Y Coordinate
		Z Coordinate
	Velocity	X Component
		Y Component
		Z Component
Detonation	PDU Header	Exercise ID
		PDU Type
		Time Stamp
	Firing Entity ID	Application
		Entity
	Target Entity ID	Application
		Entity
	Location in Entity Coordinates	x coordinate
		y coordinate
		z coordinate
	Detonation Result	8 bit enumeration
Collision	PDU Header	Exercise ID
		PDU Type
		Time Stamp
	Issuing Entity ID	Application
		Entity
	Colliding Entity ID	Application
		Entity

Table 4.3.4-1. PDU Data Fields Supporting Analysis

4.4.2 Training

During the integration week prior to the engineering experiments, all soldiers received training on the simulators in preparation for the Friday demonstration. The training consisted of rehearsing the basic USEX mission scenario (see Experiment Plan in Appendix B). During this week, the soldiers also were taken to the McKenna MOUT facility for familiarization.

4.4.3 Instructions

Written instructions were read to the soldiers prior to the experiment and before the first session of each experimental task (locomotion, search and engage, posture, outside search, inside search).

4.4.4 Trial/Session Conduct

Soldiers were assigned a unique number 1 through 8; this assignment was posted in the conference room at the LWTB that served as the soldier waiting, prebrief, and debrief area. Each day's schedule showing the task to be performed and which VIC each soldier was to be on was also posted in this room. Initially, the schedule for the entire week was posted, but as events unfolded and the schedules began to change, only the current schedule for that day was posted. The final schedule as it was conducted is presented in the Experiment Plan in Appendix B.

As indicated by the schedule, all soldiers participated in the same experimental task at the same time. However, each VIC ran on a separate exercise number so that each soldier was effectively isolated from the others during all tasks. Thus, even though all four soldiers might be performing a locomotion task in the same two sections of Building A, they would did see each or interfere with each other. Similarly, although all four soldiers were simultaneously standing in the same location in the special flat database developed for the targeting trials, they did not see each other or the targets being presented to the other soldiers. However, for data analysis purposes, each soldier's performance could be separately analyzed by sorting by exercise number (or host I.D.).

Overall, the experimental sessions took longer to conduct than anticipated. This is the opposite of our experience with the engineering experiments conducted previously under DWN. Locomotion was more difficult through the building initially, and resetting between sessions seemed to take longer. As previously noted, the result was that the decision was made to conduct fewer locomotion trials, as well as fewer search trials inside of the building (4 per soldier versus 8 planned).

As previously discussed (Section 4.3.3), the first one-half of the weapon aiming sessions were conducted using "iron sight" aiming, the remaining one-half used the IHAS aiming mode.

The following sections describe the conduct of each experiment task in more detail.

4.4.4.1 Locomotion Trials

Prior to the beginning of the engineering experiments, a plan view diagram of the routes through the southernmost townhouses was posted in the soldier waiting room. These routes (actually one route that was run in either direction) were also verbally described to all soldiers before the first locomotion session. For each of the four soldiers participating in a locomotion session, the direction was specified, along with a repetition of the requirement to go through the building as quickly as possible but not at the cost of incurring collisions with building structure. During execution of the session, soldiers could receive coaching from the VIC operators as to where they were along the path and where they should go to stay on route. When the soldiers had completed the route, they were instructed to fire their weapons to provide a data record of their completion. Simulyzer logged all data from all four VICs until the last VIC completed the course or was aborted.

4.4.4.2 Search & Engage Trials

The 48 target search and engagement trials were replicated into four sets of randomized order, then divided in half to produce 8 different orderings of 24 trials, seen in the schedule as S&E 1A, 2A, 3A, 4A, 1B, 2B, 3B, and 4B. Each soldier received all 48 trials on each VIC. The target generation software was used to generate each target, which was enumerated as a CIS soldier. Each trial began with the soldier facing north in the flat database. North was indicated by a tall pole placed at a distance beyond maximum target range. The test director announced the presentation and removal of targets, and target presentation was coordinated so all four VICs were synchronized to within a couple of seconds. Each target was presented for 20 seconds, then removed, then the next target was presented 10 seconds later (initially 5 seconds was used as the inter-trial interval but proved to be too short). If the soldier shot and hit the target, it would fall dead and remain for the rest of the 20-second interval. It would then be removed and the next trial would begin 10 seconds later. Targets not hit remained for the full 20 seconds as well. Soldiers were allowed to fire up to 3 times per target, and were instructed to return to facing north in between trials. Simulyzer recorded all PDU data from the beginning of the session until the test director announced end of session.

4.4.4.3 Posture Trials

The 48 target posture trials were replicated into four sets of randomized order, then divided in half to produce 8 different orderings of 24 trials, seen in the schedule as Post 1A, 2A, 3A, 4A, 1B, 2B, 3B, and 4B. Each soldier received all 48 trials on each VIC. The target generation software was used to generate each target, which was enumerated as a CIS soldier. Each trial began with the soldier facing north in the flat database. North was indicated by a tall pole place at a distance beyond maximum target range. The test director announced the presentation and removal of targets, and target presentation was coordinated so all four VICs were synchronized to within a couple of seconds. Each target was presented for 20 seconds, then removed, then the next target was presented 10 seconds later (initially 5 seconds was used as the inter-trial interval but proved to be too short). If the soldier shot and hit the target, it would fall dead and remain for the rest of the 20-second interval. It would then be removed and the next trial would begin 10 seconds later. Targets not hit remained for the full 20 seconds as well. Soldiers were allowed to fire up to 3 times per target, and were instructed to remain facing north in between trials. Posture and posture change requirements were monitored at each VIC, since requirements were different for each VIC. Simulyzer recorded all PDU data from the beginning of the session until the test director announced end of session.

4.4.4.4 Outside Search Trials

Soldiers began each trial by being placed at one of the four starting locations in the McKenna database (see Experiment Plan in Appendix B for routes). Soldiers were instructed how they were to proceed through the site, either north-south, south-north, east-west, or west-east along the main roads. They were instructed that targets the same as those used for the targeting trials were positioned at various locations along the route, and could be anywhere in, behind, or on top of the buildings. They were told that targets would not attack them. They were assured that the targets were visible from the route path, but they would have to look around to be able to see them. They were told initially that there could be a variable number of targets for any one trial, but eventually they found out that there were in fact exactly five targets along each route. Targets were place at various ranges at locations including the church steeple, roof of the three-story building, in windows on 1st, 2nd, and 3rd floor locations, in doorways and stairwells, and behind corners of buildings. All targets were placed in the environment simultaneously using the target generation software and were confirmed to be visible at all locations in all VICs prior to the conduct of data collection. Soldiers were instructed to shoot at the targets when located, but that it wasn't important to hit them. Most soldiers ignored this latter advice and fired until the identified targets were hit. Simulyzer recorded all PDU data from the beginning of the trial until the test director announced end of trial.

4.4.4.5 Inside Search Trials

Soldiers began each trial at one of the two starting locations used for the locomotion trials. These are locations outside of Building A but near the doorways that lead into it. Soldiers were instructed to search the entirety of the two southernmost townhouses (the same two used previously for the locomotion trials) for a variable number of dismounted infantry targets. In fact, the number of targets ranged from 2 to 4 per trial, and were placed simultaneously in the building using the target generation software. Targets would not attack the soldiers, who were instructed to search the buildings thoroughly but in a timely manner. Simulyzer recorded all PDU data from the beginning of the trial until the test director announced end of trial.

4.5 Results

The entity state, fire, detonation, and collision PDU data, along with trial condition information (range, azimuth offset, and motion) were loaded into StatView data analysis software worksheets. This package provides summarization and statistical analysis of data. StatView also provides a graphing capability, but did not have the desired flexibility. Thus, summary data was loaded into Excel to generate the graphs included in this report. Simulator sickness questionnaires, administered by ARI after the experimental sessions, showed no significant problems with simulator sickness.

Table 4.5-1 provides a general summary of overall results for each experimental task for each VIC. More detailed analyses of each task will be presented in the following sections.

In general, it can be seen that VIC Golf, with the ODT, is slowest in the locomotion task. This is consistent with observations during the tests. Variability for all VICs is high. Alpha has by far a greater number of collisions. Again, this is consistent with the observation that VIC Alpha had problems with colliding with structure and falling “up” onto the roof, especially around the top of the stairs in the southernmost townhouse of Building A.

Table 4.5-1. Overall VIC Task Performance Summary

			VIC			
Task	**Measure of Performance**	**Statistic**	**Alpha**	**Delta**	**Echo**	**Golf**
Locomotion	Time to Complete Course (Secs)	Mean	294.5	224.3	203.1	411.1
		S.D.	146.3	165.1	117.3	226.1
	Collisions	Number	835	230	283	257
Search & Engage	Time of 1st Shot (Secs)	Mean	12.9	10.5	9.9	13.4
		S.D.	4.4	4.1	4.0	4.5
	Targets Hit*	Percent	38.3%	24.7%	33.1%	14.8%
Posture	Targets Hit*	Total	63.5%	30.5%	35.2%	34.4%
		Standing	69.5%	35.9%	37.5%	36.7%
		Kneeling	64.1%	32.0%	46.9%	42.2%
		Prone	57.0%	23.4%	21.1%	24.2%
Search Inside	Targets Located	Percent	70.8%	83.3%	75.0%	62.5%
Search Outside	Targets Located	Percent	73.8%	73.8%	71.3%	42.5%

*Total targets possible = 384; 128 per posture

In the Search & Engage task, the time to locate the target, as determined by the time of first shot, shows Delta and Echo with an advantage over both the head-mounted display systems. This advantage over Alpha was expected due to field-of-view (FOV) and resolution differences, but it was anticipated that Golf, with its wide FOV and VGA resolution, might be comparable or even better than at least VIC Delta. Target engagement success reflects the generally poor shooting performance observed.

The Posture task shows an improvement in target engagement performance over that in Search & Engage. This could be explained by the fact that all targets appeared in the initial FOV and did not require search and that all targets were stationary. Performance across postures shows a consistent decrement in performance for prone targeting, even in VIC Golf where no posture changes were actually made, only eye height simulation. This result is contrary to real-life aiming, where prone shooting generally produces superior performance over kneeling and standing. However, it is consistent with weapon tracking sensor performance, which tends to degrade with increasing sensor/receiver distance.

Finally, overall search performance, both inside and out, was relatively consistent across VICs with the exception of VIC Golf, whose locomotion handicap reduced its capability to locate targets.

Each of the following sections begins with a brief restatement of the experimental task, task conditions (variables), and MOPs. This is followed by a presentation of significant differences observed among the VICs and relevant task conditions, along with any other observations of interest made during the experiments. Where statistically significant results are asserted, this means that differences were found to be significant with a probability of less than 0.05 ($p < 0.05$) using StatView's repeated measures ANOVA (Analysis of Variance).

4.5.1 Locomotion

Task: Maneuver along a route through southernmost two townhouses of Building A in the McKenna MOUT database, attempting to complete as quickly as possible without colliding with building structure.

Task Conditions: Alternate directions along route.

MOPs: Time to complete course; number of collisions with building structure.

Figure 4.5.1-1 shows a plot of both average time to complete a locomotion trial (line graph) and the average number of collisions per trial (bar graph) across all four VIC. Performance on the A and B (reversed) routes were compared and no differences were found, so the data for these two courses has been combined for the rest of the analysis. Differences among the VICs are statistically significant for both collisions and time.

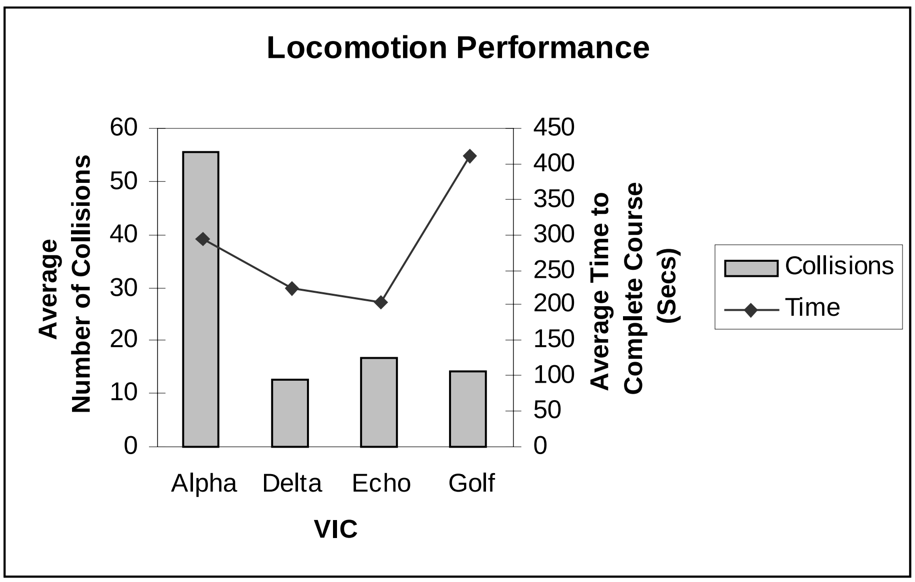


Figure 4.5.1-1. Locomotion Task Results

The chief contributor to the time difference is VIC Golf, which was substantially slower than either of the other three VICs. All VICs had been requested to limit their maximum velocity to 3.5 meters/sec. A limited check of the entity state data showed cases where VICs Delta and Echo exceeded this limit up to about 5 m/sec. Alpha had a few cases where the velocity exceeded 3.5 m/sec by less than 0.5 m/sec. Golf had no cases exceeding the threshold.

The collision difference was due to Alpha's significantly greater number of collisions as compared to Delta, Echo, or Golf. Again, Alpha had problems of encountering cracks between polygons in the database (explanation provided by Alpha personnel) that caused their clamping algorithms to produce anomalous behaviors such as popping up onto the roof. It should also be noted that since all VICs except Alpha were based on the same simulator, differences in collision detection and bounding regions existed only between Alpha and these three VICs. Thus, one might expect the SVS-based simulators to perform comparably in collision measures.

No clear evidence of increasing performance over trials was seen for either course completion times or collisions.

As previously stated, these locomotion trials test more than the implementation of self-movement for each VIC. This task also depends on the visual system and on the quality of the database. For in order for a soldier to find his way quickly and accurately through the environment, the necessary visual cues must be present to support this task. One obvious deficiency in this area is the visual database, particularly inside of buildings. The McKenna database used during these tests applies a cinder block texture to the interior walls. Lighting and shading is inadequate to provide contrast between adjoining walls or walls seen through a doorway. Indeed, doorways themselves are hard to discern. The resultant impoverished visual cues present a near visual *ganzfeld*, or homogenous visual field, that can lead to disorientation and an inability to judge self motion, depth, and distance.

As for the locomotion devices, some soldiers liked the thumb transducers used by Alpha, Delta, and Echo, while others did not like their lack of realism (see comments in USEX section). The ODT, having proved its potential in the original DWN, did not contribute any new data to DWN ERT. It is awkward, cumbersome to use, and slow, but many soldiers like the realism of walking to move through the virtual environment.

4.5.1.1 Live Exercise Comparisons

Part of the experiment plan was to conduct tests at the actual McKenna MOUT site so that comparisons might be made between live and virtual performance. On the morning of Thursday, July 16, the soldiers were taken to this MOUT site and asked to perform tasks including following the locomotion routes that they had practiced on the simulators. ARI personnel followed the soldiers through the buildings to aid them in staying on the route and also to note any errors in route following. Time to complete the route was measured with a stopwatch. Plans to use the existing MOUT instrumentation system were abandoned when it was discovered that one of the townhouses that the route passed through was not instrumented. During this live exercise, soldiers also practiced building assault and room clearing operations to serve as a point of comparison for the following week’s user exercise phase of DWN ERT tests.

A comparison of the average times for each soldier for both the virtual and live locomotion tests is shown in Table 4.5.1.1-1. Two trials, one in each direction, were run at McKenna. As can be seen, live execution times are significantly shorter (an average of over four times shorter) than virtual times. Also included in the table is the minimum time achieved by each subject in the simulator. Assuming these reflect actual performance and not an abnormal run for some reason, then it appears possible that with sufficient training, virtual performance may be able to approach real world performance. What achieving this level of performance would mean in terms of the overall operational fidelity of the simulators is unclear.

Table 4.5.1.1-1. Virtual-Live Locomotion Time Comparison

Soldier	Virtual Times*	Live Times	Virtual Minimum Times
1	318	80	95
2	234	76	105
3	309	69	88
4	336	58	83
5	213	70	100
6	303	65	113
7	192	60	119
8	371	76	67

*All times are in seconds

4.5.2 Search & Engage

Task: Soldiers standing in a fixed position attempt to locate DI targets and engage them with their weapons. A specially constructed dish-shaped database was used for these trials. The flat portion of the dish had a radius of 200 meters for target placement.

Task Conditions: Target Range: 25, 50, 100, 150 meters
Target Speed: 0, 4, 8 miles per hour
Target Azimuth Offset: 80°, 130°, 230°, 315°

MOPs: Time to acquire target; target engagement performance (hits)

The purpose of this task was twofold. First, it was intended to test the simulators' ability to search for and locate targets located at different range and azimuth locations relative to the observer, targets that were both stationary and moving. While range and motion differences are easy to conceptualize, Figure 4.5.2-1 is provided to illustrate the differences in azimuth offset from the soldier.

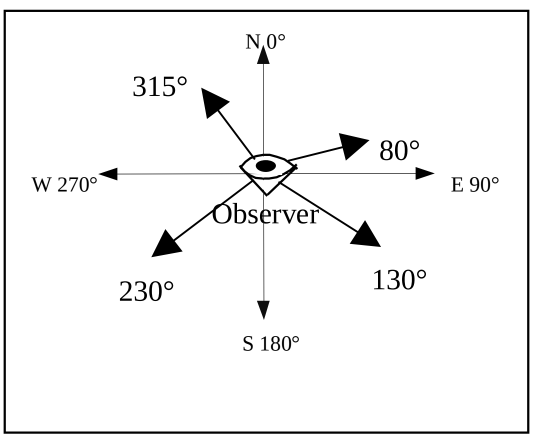


Figure 4.5.2-1. Azimuth Offsets Relative to Observer

The second purpose was to assess the capability of the simulators to provide accurate weapon aiming in the basic "iron sight" mode, that is, unaided by sighting mechanisms such as a simulated Land Warrior IHAS. This would provide a stronger test of the sighting technology used by the simulators. In fact, there were only two sighting systems used in DWN ERT – VIC Alpha's video-tracked 'virtual rifle' and the SVS's InterSense combined inertial/acoustic tracking system. The results of both of these efforts are described in the following sections.

4.5.2.1 Target Search Performance

For the purposes of this analysis, the time to locate and acquire the target is defined as the time between when the trial began (target appearance) and when the soldier fired his first shot. A comparison of the averages of these times for the four VICs is shown in Figure 4.5.2.1-1. The observed differences are statistically significant, with the primary differences found between the HMD-based systems (Alpha and Golf) and the projection display systems (Delta and Echo). Performance within similar systems (HMD or projection) is comparable. The major difference between these particular pairings of VICs does seem to be type of display. Both Delta and Golf have VGA resolution, Alpha is less than VGA, and Echo has XGA resolution in the center channel and VGA in the sides. Golf has a much wider FOV than Alpha, and Echo has a much wider FOV than Delta. Thus, the main commonality between the VICs with similar performance seems to be display type. The HMD displays are significantly slower in firing at targets than are the projection displays.

One confounding aspect of the simulators that complicates this seemingly straightforward distinction is that both Alpha and Golf use a virtual rifle for aiming, whereas both Delta and Echo use a physical rifle mock-up. It could be the difference in performance is due to the fact that it takes longer to aim with a virtual rifle than a physical one. There is no way with the present data to definitively select one alternative explanation over the other. This issue of whether the time-to-fire MOP is measuring visual system or aiming performance will be discussed as related data is presented.

It also must be noted that during the early trials for this and the posture aiming trials, VIC Alpha was not removing targets as soon as the remove bit was set, they would wait until they timed out to remove them. This resulted in the targets remaining on the database for a longer period than intended (at least five seconds) and often resulted in two targets appearing at once. Obviously, this caused confusion for the soldier on Alpha. This was corrected the first day.

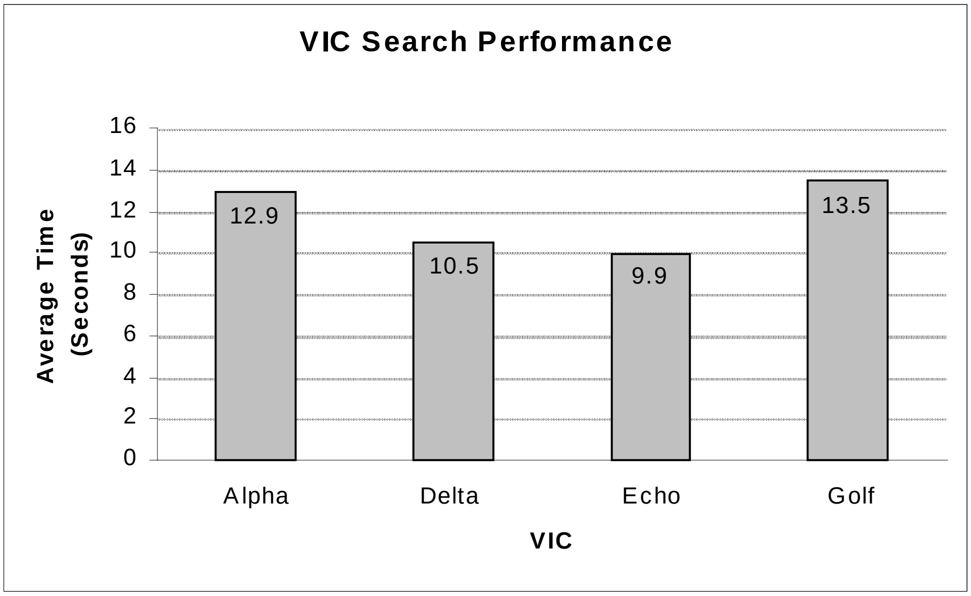


Figure 4.5.2.1-1. VIC Target Search Comparison

It was hypothesized that azimuth offset would help determine differences among the VICs in their ability to move the display line of sight (LOS) during search. It was anticipated that HMD-based systems might perform better since it provides a more natural search method, provided the resolution and FOV is adequate. The results of the VIC by azimuth comparison are shown in Figure 4.5.2.1-2.

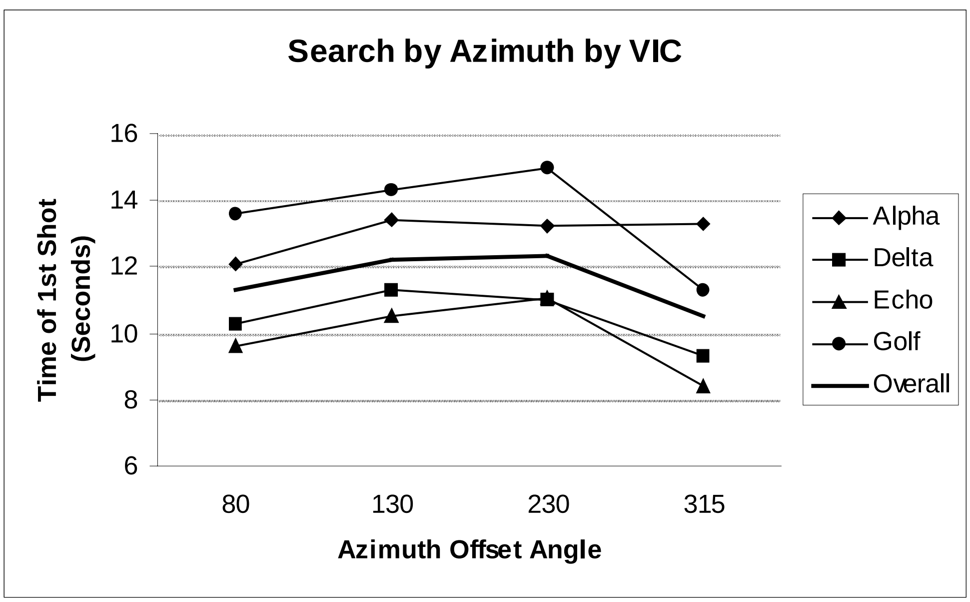


Figure 4.5.2.1-2. VIC Target Search By Azimuth Offset

There is a significant azimuth main effect as well as azimuth by VIC interaction. Since the soldiers started each trial with an initial heading of 0 degrees (due North), the order of offsets in increasing distance from north is 315, 80, 130/230 with both of the latter being the same distance but on opposite sides. This order is generally reflected in the observed data, with the apparent exception of VIC Alpha, which shows relatively constant performance for all azimuths except for 80º. It is not clear why this is so.

Target range was also expected to effect VIC target acquisition performance differentially based on the performance of the visual system. Figure 4.5.2.1-3 shows that the significant range main effect found appears to affect all VICs similarly, i.e., there is no VIC by range interaction. Statistical test of this interaction was not possible since the software encountered a "sum of squares and cross product (SSCP)" matrix singularity, which, according to the message accompanying the notice of this failure, can be caused by an excessive number of missing data values. This SSCP singularity was encountered several times over the course of the analysis, primarily with comparisons involving target range. This singularity is probably caused by the data values at 150 meters, where both VICs Golf and Delta especially had many missing data values.

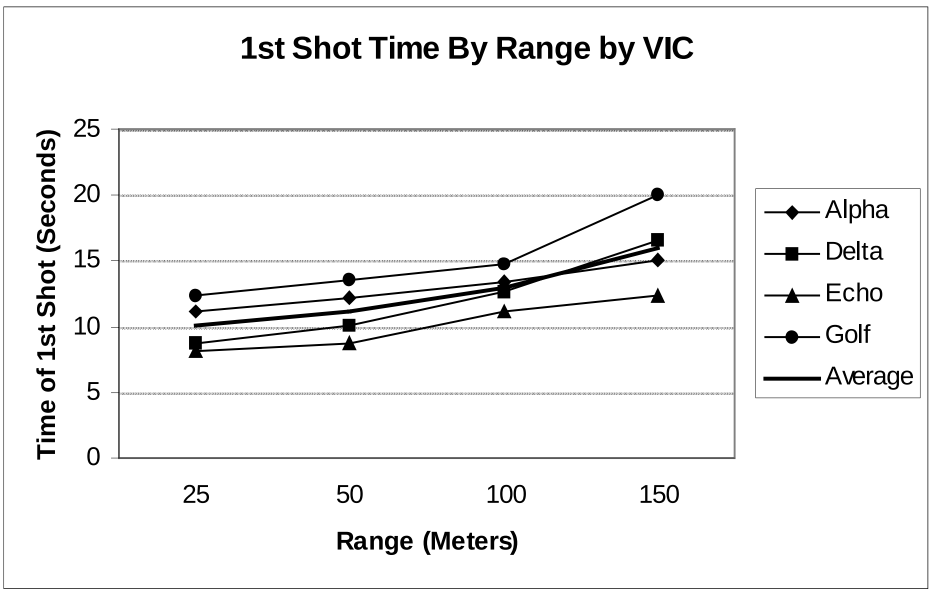


Figure 4.5.2.1-3. VIC Target Search By Range

The number of 1st shots for each VIC as a function of range is illustrated in Figure 4.5.2.1-4. The paucity of data for VICs Delta and Golf at 150 meters can readily be seen in this figure.

The observed range effect in Figure 4.5.2.1-3 is what would be expected, that the average acquisition time increases with increased target range. Again, all VICs appear to follow the overall trend; no one VIC appears to deviate exceptionally from the average. Additionally, the reduced number of shots taken as range increases argues that for at least this measure, the limit in performance is the visual systems, not ease of aiming.

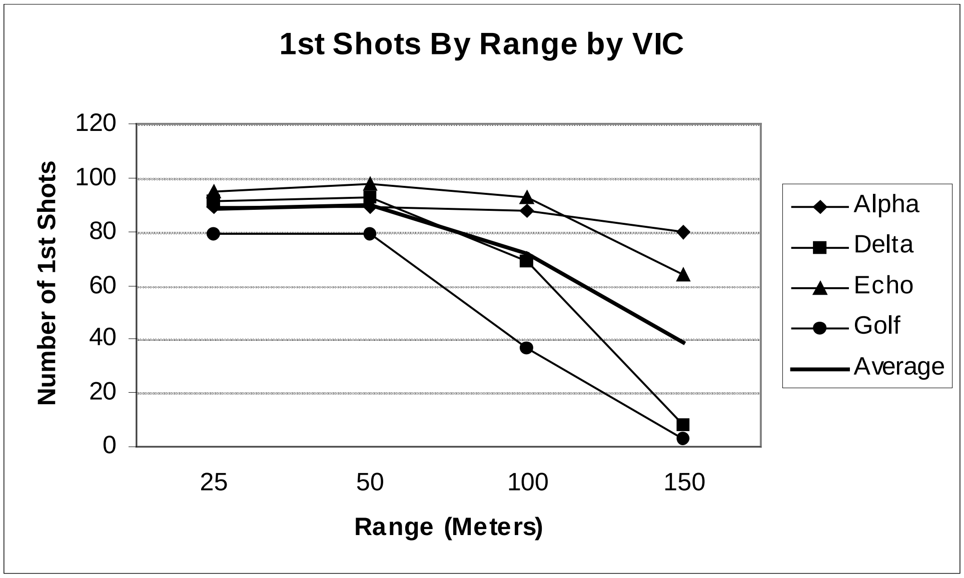


Figure 4.5.2.1-4. Number of 1st Shots per VIC By Range

Finally, target motion was anticipated to have an effect on target acquisition performance. It is known that in most situations, a moving object is easier to detect than a stationary one. The results shown in Figure 4.5.2.1-5 indicate a small but statistically significant reduction in times for the moving targets as compared to the stationary targets. There was no speed x VIC interaction found.

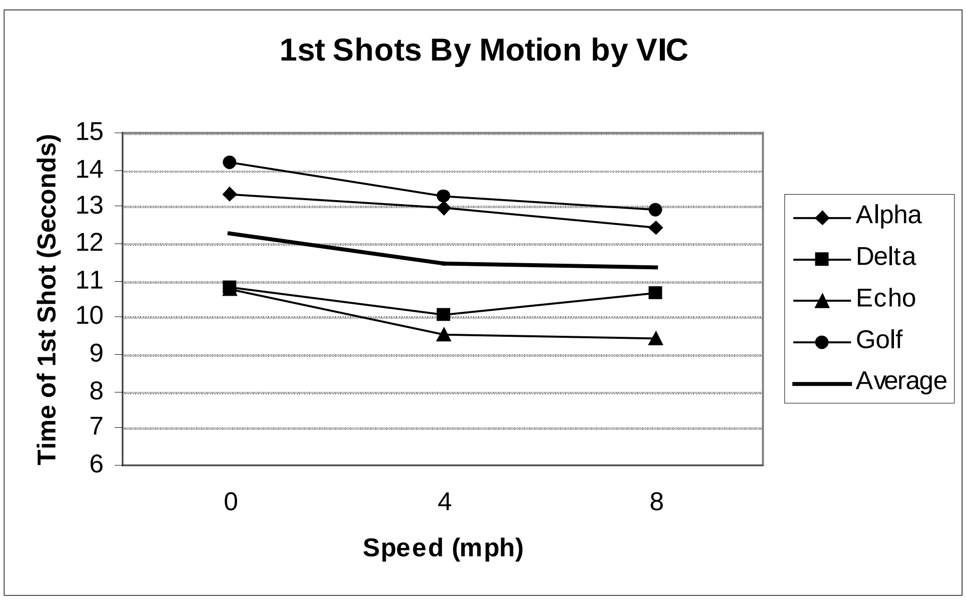


Figure 4.5.2.1-5. VIC Target Search By Target Speed

Here as well, it can be argued that aiming should be more difficult for moving than stationary targets (arguably supported by the reduced number of hits on moving targets versus stationary ones seen in the next section) and should therefore take longer. Since times here are shorter for moving targets, this would support the notion that time of fire effects are primarily visual and not due to aiming differences.

4.5.2.2 Target Engagement Performance

During the first day of the experiments, it became obvious that the SVS InterSense tracking system was not providing adequate performance. Soldiers were complaining that they couldn't hit anything and their morale was suffering. It was apparent from the shots' 'splashes' on the ground that aiming was significantly off. Thus, the decision was made to finish the first half of the trials using the weapons' "open sights" and use each VIC's IHAS simulation during the second half of the trials. This was an alternative to aborting the aiming trials altogether since system performance on the SVS-based systems was poor and soldier effort was flagging.

Given this, the obvious comparison to make initially is target hit performance for the open sight versus IHAS trials. This is shown in Figure 4.5.2.2-1 for overall number of hits per VIC, in Figure 4.5.2.2-2 for percent of target hits for each VIC.

The two presentations show that these two measures, number of hits and hit percentage, yield different absolute values but exhibit the same overall pattern of results. Further analyses will use only number of hits as the measure of performance, since this is the measure used for the statistical analysis of the data.

Analysis of the sighting data yielded significant sight effects, VIC effects, and a significant sight by VIC interaction. Performance differences for the two sighting systems are less for Alpha than for any of the other VICs. This is primarily due to the fact that the "open sights" for Alpha were generally accepted as adequate, and Alpha's IHAS implementation crowded an already small HMD FOV, so many of the soldiers opted to use the open sights only. Since sight performance for Alpha is comparable in any case, and since iron sight performance for the other VICs contributes little to the total and does not alter the observed pattern of results for IHAS versus combined, the data for these two conditions are pooled for the following analyses.

The task conditions that could influence target engagement performance include target range, azimuth offset, and motion. Of these, target azimuth offset had no significant effect on hit performance. The effects of target range and speed on performance are discussed in the following sections. A significant overall VIC effect was found, as shown by the composite Overall VIC lines in Figures 4.5.2.2-1 and 4.5.2.2-2.

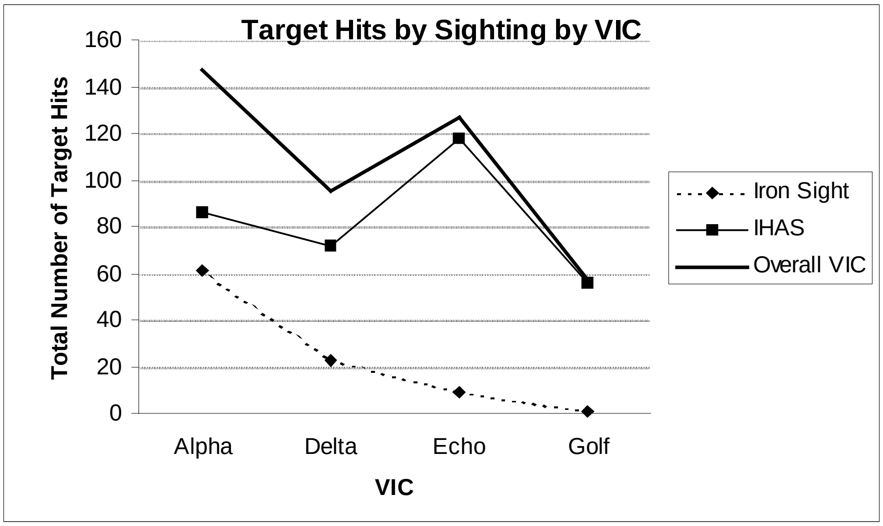


Figure 4.5.2.2-1. Number of Targets Hit by VIC by Sight (out of 384)

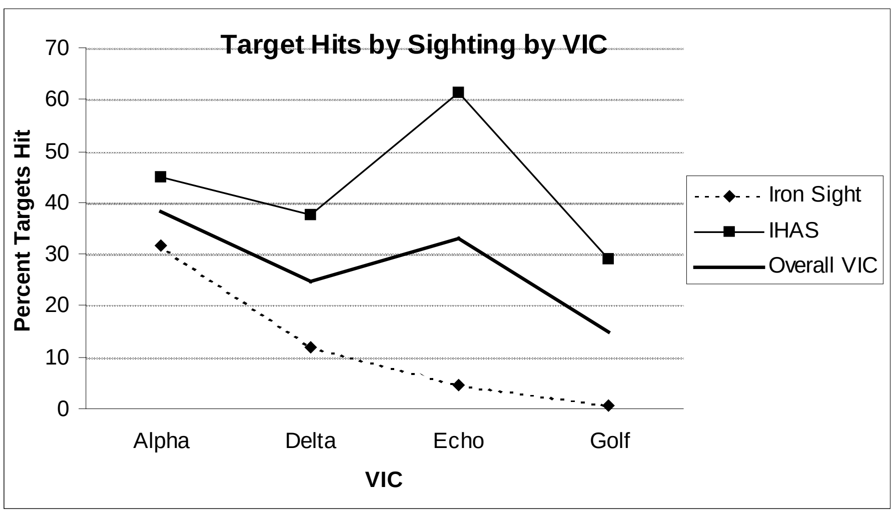


Figure 4.5.2.2-2. Percent of Targets Hit by VIC by Sight

Figure 4.5.2.2-3 shows the effect of target range on the number of targets hit by each VIC. There is a significant range effect, indicated by the Average VIC dark line. The obvious effect is a rather precipitous decline in hits as target range increases. Since there were 96 target presentations at each range, the maximum hit percentage is around 67% for VICs Alpha and Echo, falling to zero or near zero at 150 meters. A VIC by range interaction could not be tested due to the SSCP singularity discussed previously. It does not seem that an interaction would be expected. A comparison of VIC shooting performance with one measure of real-world soldier shooting performance over these ranges is discussed in Section 4.6.2 (see Figure 4.6.2-2).

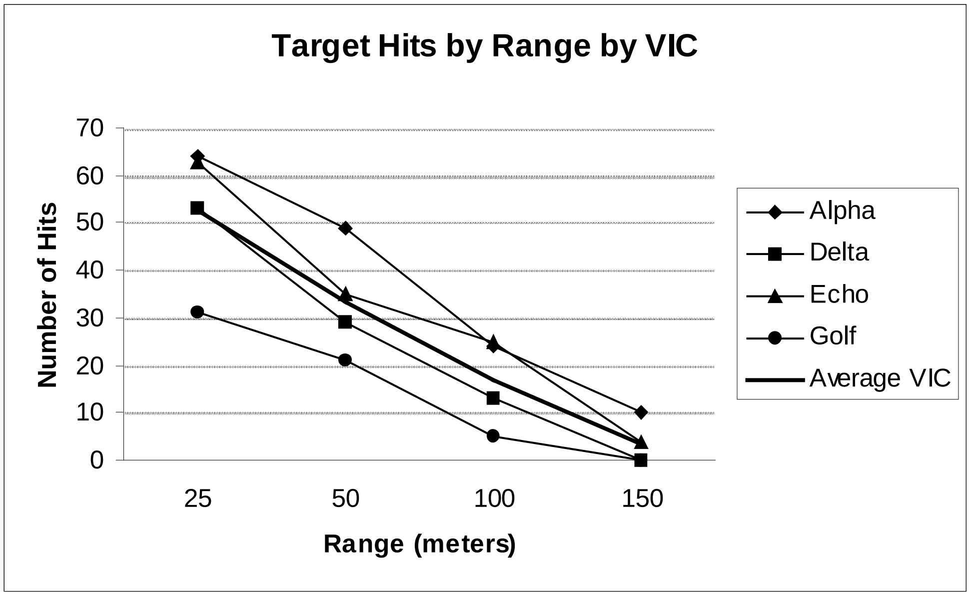


Figure 4.5.2.2-3. Number of Targets Hit by VIC by Range (out of 96)

The effect of target motion on hit performance is shown in Figure 4.5.2.2-4. This effect is significant, a VIC by target motion interaction was not. It is apparent that increased target speed

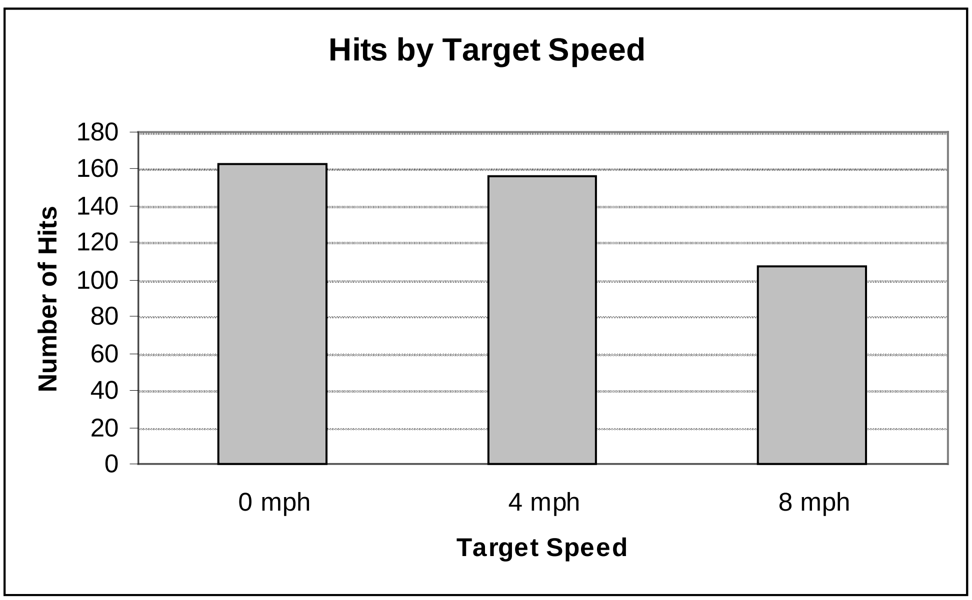


Figure 4.5.2.2-4. Number of Targets Hit by Target Speed (out of 512)

results in decreased numbers of targets hit. This is not surprising; real-world performance would produce a similar pattern of results.

Finally, the number of hits for each of the three allowed shots was compared. It could be speculated that if aiming errors were consistent, soldiers could "home in" on the target and thus increase their hit percentage over the number of shots. Although the differences observed were statistically significant, the percentage of hits ranged from 17 percent for the 1st shot to 13 percent for the 3rd (2nd shot was 15 percent). Thus, the pattern of differences is very small and contrary to the hypothesis. Observation of soldiers during the experiment seem to confirm that aiming errors were not consistent enough to adjust fire to increase the chance of hit within three shots.

4.5.3 Posture

Task:	Engage stationary targets appearing in soldier's initial field of view from three postures.
Task Conditions:	Target Range: 25, 50, 100, 150 meters Target Azimuth Offset: 10°, 20°, 345°, 355° Posture: Standing, kneeling, prone
MOPs:	Target engagement performance (hits)

The posture trials were run intermixed with the search and engage trials, so all simulator conditions existing for these trials also existed for the posture trials. Thus, the posture trials were affected by the decision to perform half the trials with open sights and half with IHAS. Figure 4.5.3-1 shows VIC performance in the posture trials for each of the sighting conditions, along with an overall measure of VIC performance.

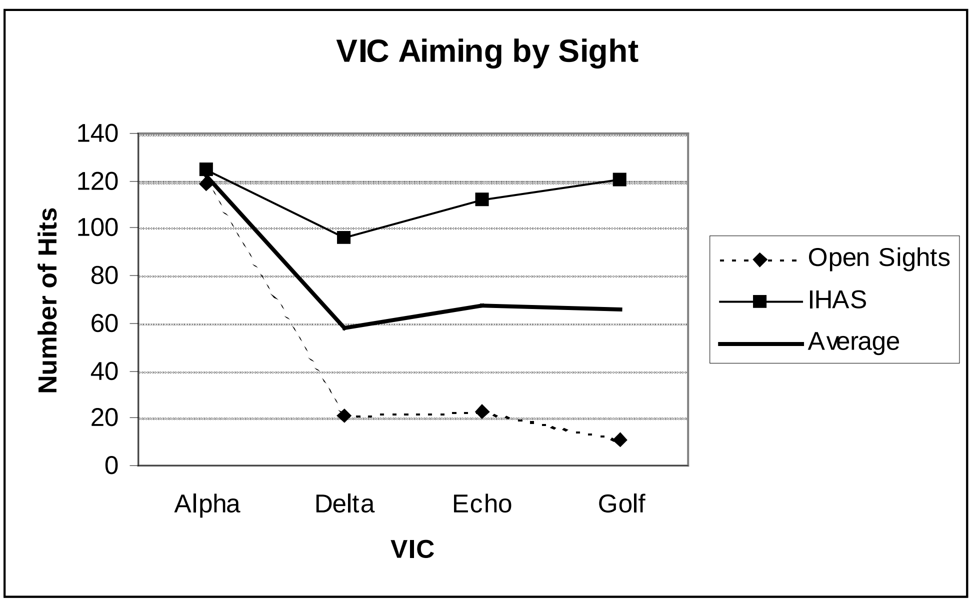


Figure 4.5.3-1. Posture Trial Target Hits by Sighting (out of 384)

As might be expected from looking at the graph, there is a significant difference among the VICs in overall performance. The primary difference was that VIC Alpha performed better than each of the other three systems under both sighting conditions. (Again, VIC Alpha's implementation allowed soldiers to use either open sights or IHAS so it is unclear if IHAS was strictly used under the IHAS condition. Indeed, it probably was not.) Once again, sighting differences effect the magnitude but not the pattern of results. The statistical difference is due to Alpha's performance; the performance of the other three VICs do not significantly differ from each other, according to post hoc analyses. Given this, subsequent analyses will pool the results from the two sighting conditions. The differences in azimuth target placement were simply to add variability to target location so as to foil prediction of where targets would appear. All targets appeared within the initial FOV of the soldier in each simulator (+20°, -15°). Thus, target azimuth location was not evaluated as a task variable, only soldier posture and target range were analyzed.

Obviously, the major effect of interest for this task is that of soldier posture. The graph of the effect of posture for each VIC is shown in Figure 4.5.3-2.

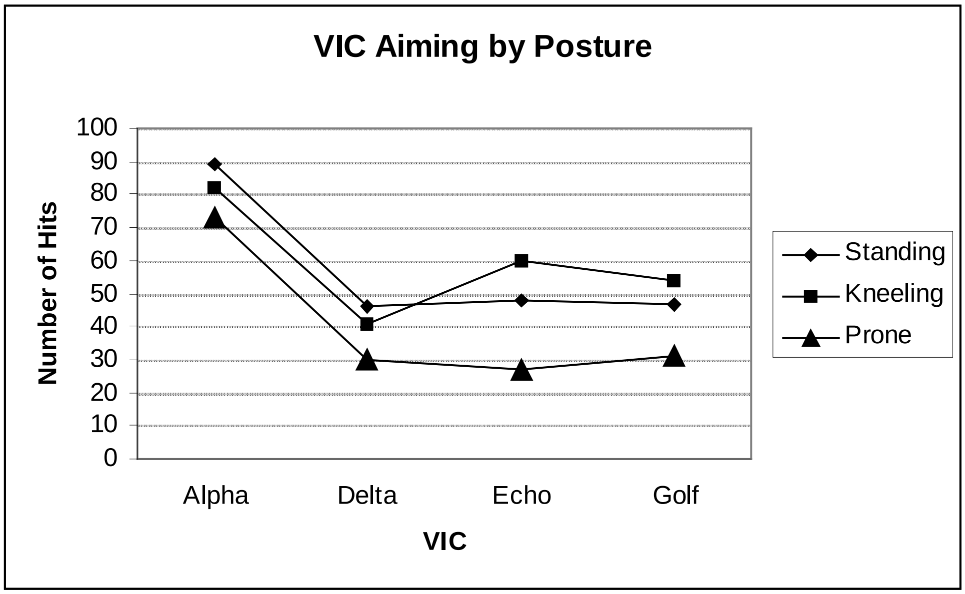


Figure 4.5.3-2. Number of Targets Hit by VIC for Each Posture (out of 128)

There is a significant effect of both VICs (as already noted in the sighting discussion) and posture individually, but the VIC x posture interaction was not significant. These effects can be seen in the Figure – the VIC difference is the same as seen in the previous Figure (Figure 4.5.3-1), and the posture effect can be seen by the displacement of the posture lines. The major contributor to the posture effect is the differences between prone and the other two postures; the difference between standing and kneeling is not significant. Prone shooting performance is the worst of the three postures for each VIC. This is not unexpected for Delta and Echo, whose sighting technology predicts degraded performance as the difference between the transmitters and receivers increases. Alpha should be posture-neutral in terms of its video tracking. Golf should be unaffected by posture changes, in terms of soldier tracking, since the user does not actually physically change postures. He simply presses a button on the rifle to round-robin select through the three postures.

In addition to the tracking aspects, posture changes effect the eyepoint (and weapon point) in the simulated world. In Golf's case, this is the only change due to posture differences and can be the only explanation for differences in performance across postures. It was noted that on Delta, and possibly on Echo as well, when the soldier assumed the prone posture, his eyepoint was sometimes under the ground plane, since all the soldier could see was a blue field on his display. In these cases, the soldier had to unnaturally raise himself up on his elbows and stretch his neck up to see the terrain. This made aiming difficult and could account for decreased performance on these trials. This did not always happen – what exactly caused this is unclear to the author.

The effect of target range on hit performance can be seen in Figure 4.5.3-3. The effect is similar to that seen for the search and engage trials (Figure 4.5.2.2-3) – hit performance decreases substantially over increasing target range. The main range effect is significant; the range x VIC interaction could not be tested due to the SSCP singularity problem. Judging from the graph, an interaction would not be expected.

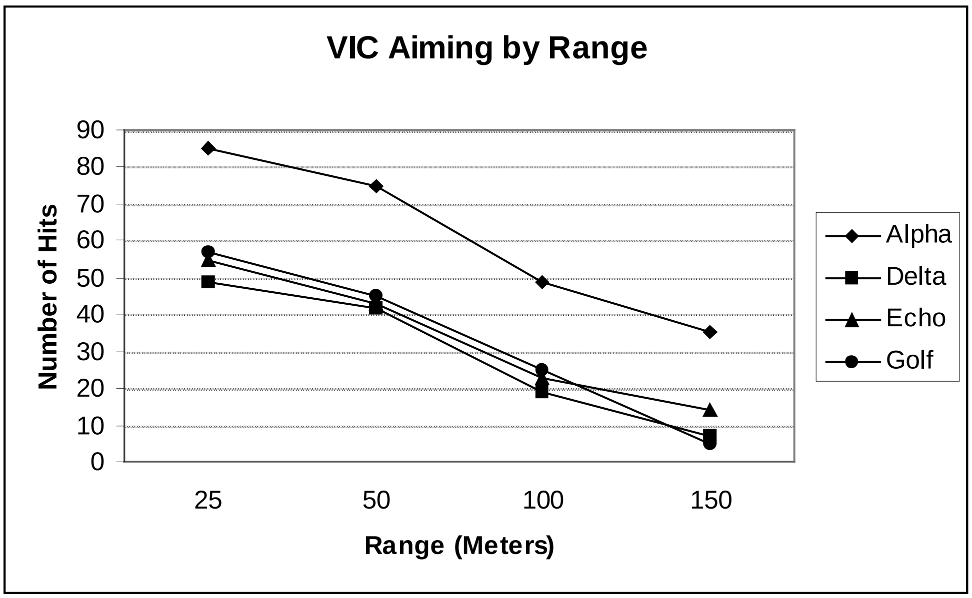


Figure 4.5.3-3. Number of Targets Hit by VIC for Target Ranges (out of 96)

With significant soldier posture and target range main effects, an analysis was performed to look for a posture by range interaction. That is, does soldier performance over target ranges differ depending on which posture is being used. This analysis yielded a significant interaction effect, which is shown in Figure 4.5.3-4. At the closest range (25 meters), performance among the postures is comparable. At the intermediate ranges, prone performance is substantially worse than either standing or kneeling. At the extreme range (150 meters), performance for all postures converges to the same low level. This demonstrates the interaction or differential effects of posture with respect to target range.

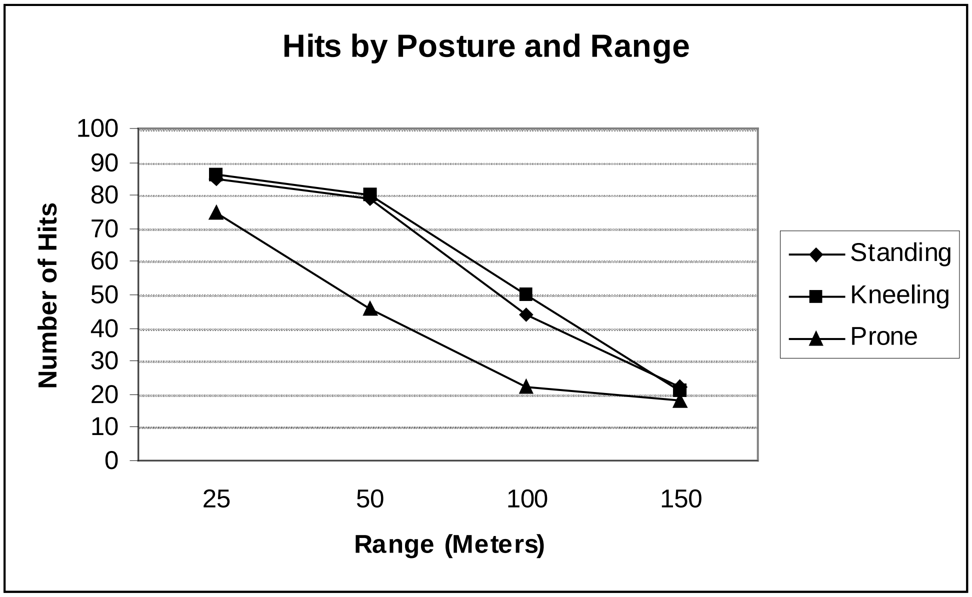


Figure 4.5.3-4. Number of Targets Hit by Range for Each Posture (out of 128)

In summary, the posture trials did result in performance differences among the VIC. These effects must be allocated to both sensor and to simulation causes. How to allocate these effects among and within the four VICs is an open question at this time.

4.5.4 Search Inside

Task: Search through southernmost two townhouses of Building A in the McKenna MOUT database, attempting to locate stationary DI targets positioned in various places.

Task Conditions: Number of DI targets: 2, 3, or 4

MOPs: Number of targets located.

The intent of this task was to emphasize close-in search requiring (in real life) a lot of head and body movement in the horizontal plane primarily. Soldiers would have to maneuver through the building while looking around corners and into doorways to see if anyone (the generic target entity) was inside. Since the targets were known by the soldiers to be non-reactive, i.e., the targets would not shoot at the soldiers, then they did not employ as much stealth as they may have otherwise. They basically walked into rooms and looked around for targets. Targets were shot if found, in accordance with instructions. If targets were missed, it was primarily due to the fact that the room that the target was in was skipped during the search process. The soldier's difficulties encountered in the locomotion trials, such as moving through the building and knowing where they were within the building, were evident in these trials as well.

Figure 4.5.4-1 shows search performance by VIC. No significant differences were found. The largest observed difference in targets found (between Delta and Golf) represents five out of the 24 total targets (per VIC). Time to complete the search was initially considered as a measure of performance, but after further reflection it is not clear what this measure would indicate if differences were found. There is also no clear indication of when a search has been completed by a soldier.

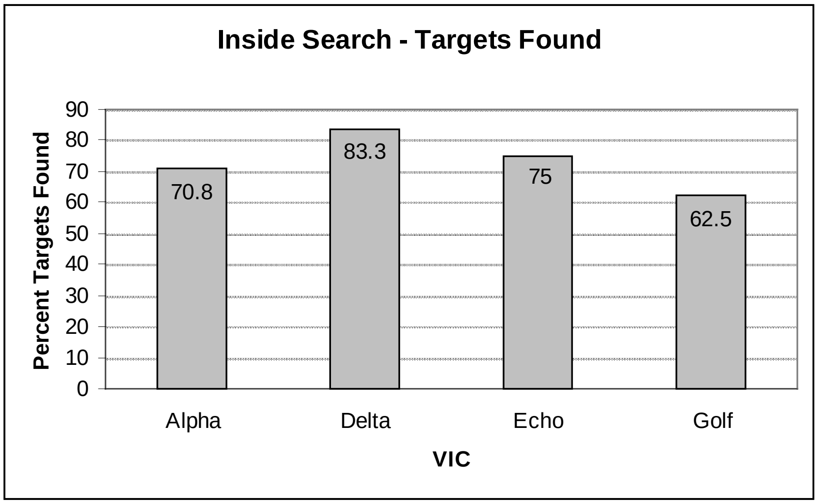


Figure 4.5.4-1. Percent Targets Located by VIC During Inside Search

4.5.5 Search Outside

Task: Maneuver along an outside route through the McKenna MOUT database, attempting to locate stationary DI targets positioned in various places.

Task Conditions: Route: North-South, South-North, East-West, West-East

MOPs: Number of targets located.

The rationale for the outside search task was similar to that of inside search, except that it was thought that it would allow greater opportunity to introduce a vertical component to the search task. Placing targets in second- and third-story windows, as well as on roofs and in the church steeple, should emphasize differences among the VICs with respect to their ability to control their LOS in the vertical as well as horizontal plane. Potential differences between the fixed display systems (Delta and Echo) and HMD-based systems (Alpha and Golf) were hypothesized.

Soldiers were instructed to shoot at the targets once they were found, but that it wasn't important to hit them. It was expected that the direction of fire could be determined from the fire PDU, then use this to see which of the targets had been located. However, since the SVS-based systems do not record the velocity vector of the round, this analysis was not possible. Instead, the Simulyzer log files were replayed and, using the Simulyzer plan view display (PVD), fire events were monitored to assess which target was being fired upon. This data was manually recorded then entered into a StatView data file.

The results for the outside search task are presented in Figure 4.5.5-1. Analyses were conducted to see if there were differences among the different courses used or the alternate target layouts used for each course. No significant differences were found, so the data for all these conditions was pooled for the overall VIC comparison. Analysis of VIC performance did find a significant difference among the VIC, although the primary effect was between Golf and the remaining three VIC. VIC Golf was the only one to have any significant number of trials in which one or no targets were found. VICs Delta and Echo each had a trial with only one target found, but this was during a session in which the soldiers had been started at the wrong location and instructed to follow the wrong route. VIC Echo had an additional trial in which one target was found, but a problem caused this trial to be terminated prematurely.

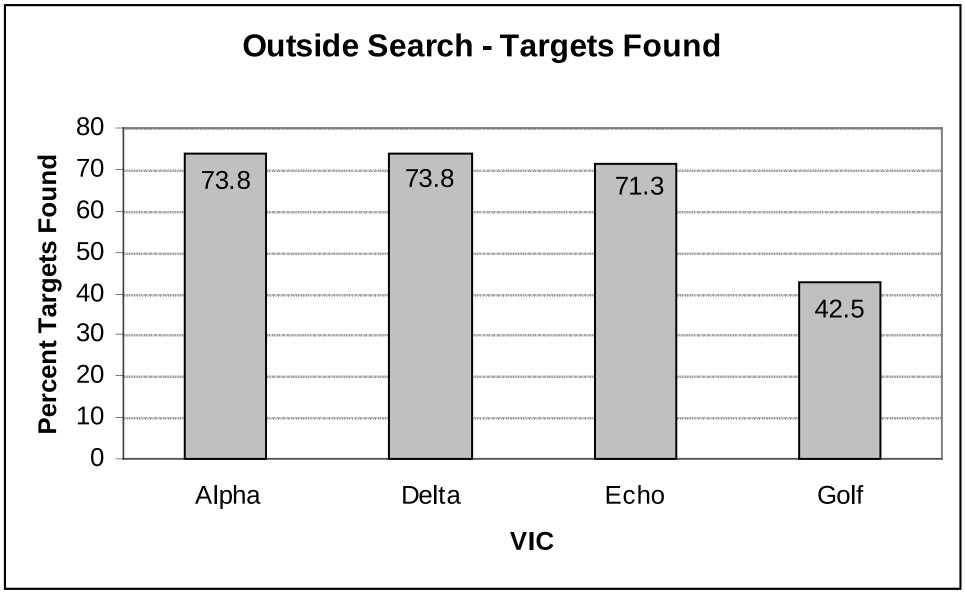


Figure 4.5.5-1. Targets Located by VIC during Outside Search

Of the six trials in which Golf found one or no targets (three one, three none), four were due to two soldiers. All of these trials showed Golf activity, but either the wrong route was taken or not much searching was taking place. For example, on one north-south route, the soldier went west at the intersection and continued to the end of the road. Apparently, the operator at that station did not notice. Another time, the soldier made an apparent beeline from one end of the route to the other, with no searching for targets evident. There were definitely no shots fired. Apparently, for some soldiers, simply moving and finding their way on VIC Golf was difficult enough to preclude other tasks from being attempted.

In attempting to identify patterns of targets missed, those targets placed on a 3rd floor or higher (roof or steeple) were identified (seven of the 40 target locations). None of the VICs missed many of these (Alpha missed 1, Delta 3, Echo 2, Golf 5), indicating that most of the targets missed required the VIC to look to the side through doorways and windows. One explanation for this lack of a vertical target placement effect could be that most of the elevated targets could be seen at ranges sufficient for them to fall near or within the vertical FOV of the systems at that range. Anecdotal observations of VIC Delta confirm this for some targets, especially those in Building L (the three-story building).

4.6 DI SAF Performance on Engineering Experiment Tasks

Section 7 of the DWN ERT Experiment Plan (Appendix B) discusses plans to have the DI SAF perform all of the engineering tasks that the soldiers would perform. This was based on the assumption that DI SAF would have a good deal of autonomous behaviors that could be validated against (virtual) human performance. As the experiments drew near, these plans were assessed against the levels of performance that would be available in the DI SAF during this period. This assessment is summarized below.

a) Locomotion. Since routes that DI SAF use to move through buildings have to be laid out by hand by the SAF operator, the only variable in SAF performance would be its speed along this route. Since this too can be programmed by the operator, virtually any level of performance desired could be achieved. Thus, conducting this test did not seem to be productive at this time.

b) Search Outside. The assessment by the DI SAF developers was that current search algorithms would not discover targets on top of roofs or in upper story windows. Also, the SAF would not be able to detect targets inside of any buildings except for Building A, for which an MES structure had been developed. Thus, the same task conditions could not be run for the SAF as was to be used by the VIC.

c) Search Inside. Much like the locomotion trials, a route could be constructed by the operator that would ensure that every target would be located. Since this is known *a priori*, it was not deemed necessary to prove this by performing the work to execute this task.

d) Posture Aiming Task. Since the database used for this and for the search and engage trials was perfectly flat, the DI SAF developers said that varying the posture of the SAF shooter would have no effect on the search and engagement algorithms. Therefore, the posture variable would have no effect on performance. This left only range, which could be assessed during the Search & Engage trials. Thus, this task too was not performed.

This left only the Search & Engage trials to be conducted. A CTDB version of the flat database was constructed for the SAF, and two complete repetitions of all trials were conducted. A small circular route was programmed for the SAF so that it would search 360° about the center of the database. This search behavior was released each time a target was placed on the database. PDU data was logged as during the soldier trials.

The results of these tests are presented below as comparisons against average VIC performance for the same conditions. No statistical analysis was conducted on the DI SAF data because of the small sample size. A *t* test was performed to confirm the obvious fact that there is a difference between DI SAF and VIC performance. The results were significant.

4.6.1 Search Performance Comparison

Figure 4.6.1-1 shows the overall performance difference between the VICs and DI SAF in the time of 1st shot, used as the measure for target detection and acquisition performance.

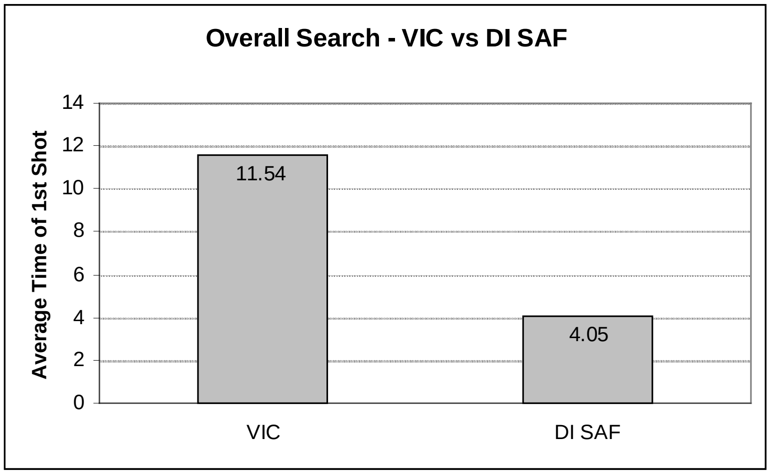


Figure 4.6.1-1. Average Acquisition Time (seconds) – VIC vs DI SAF

As can be seen, DI SAF took significantly less time than the VIC in acquiring targets. Further comparisons of these performance differences are presented below.

Figures 4.6.1-2 through 4 compare VIC and DI SAF target acquisition performance as a function of target range, azimuth offset, and motion. As can be seen, VIC and DI SAF performance parallel one another for most of these comparisons, except for the larger range effect for the VIC. This lends support that the search processes used by DI SAF are analogous to those used by the soldiers, at least as they performed them in the VIC. There is, however, an absolute performance difference that reflects either too-good performance by the DI SAF or sub-optimal performance by the soldiers in the VIC (or, of course, both of these effects).

Figure 4.6.1-2. Average Acquisition Time Range Effect

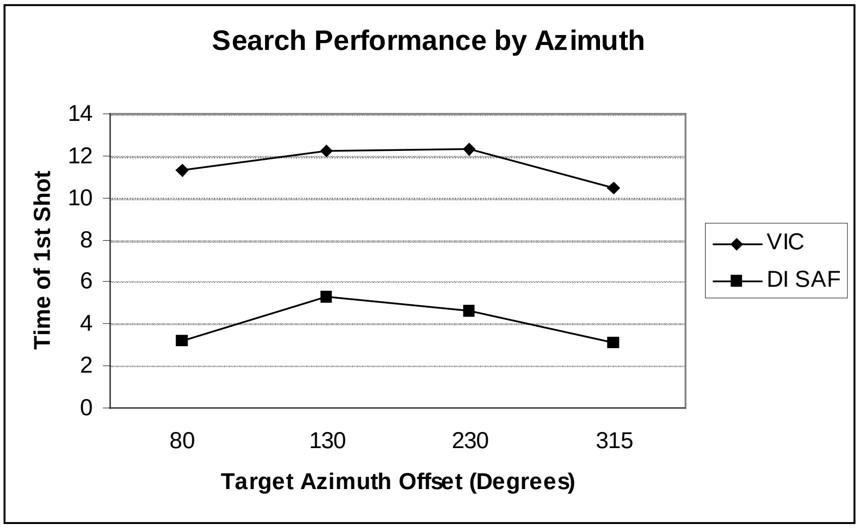


Figure 4.6.1-3. Average Acquisition Time – Azimuth Effect

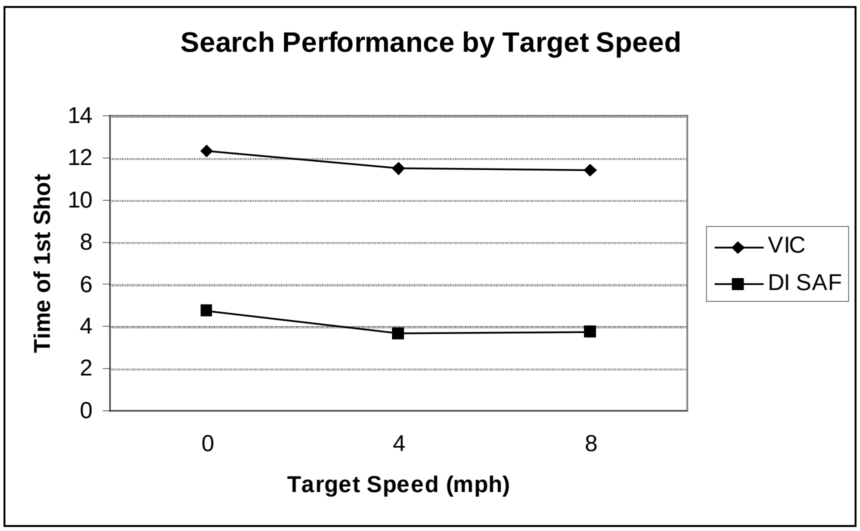


Figure 4.6.1-4. Average Acquisition Time – Target Motion

4.6.2 Target Engagement Performance Comparison

Given the shooting performance exhibited by the VIC, it is a fairly safe hypothesis that the DI SAF would perform better in this aspect of the task as well. The results of the overall VIC – DI SAF comparison, presented in Figure 4.6.2-1, overwhelmingly confirm this hypothesis. As can be seen, the VIC hit less than 1/3 of all targets, while the DI SAF hit over 90% of all targets. Acknowledging this gross performance difference, the pattern of results over the trial conditions will be assessed in the following paragraphs.

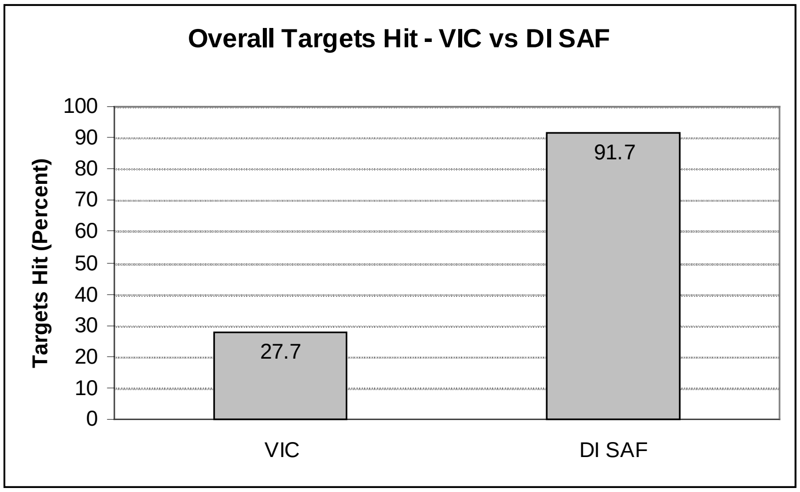


Figure 4.6.2-1. Percent Targets Hit – VIC vs DI SAF

Figures 4.6.2-2 through 5 show the pattern of results for target range, motion, azimuth offset and by shots fired. All effects were significant among the VICs except for azimuth effects. In the first three graphs (2 through 4), the pattern of results between the VICs and the DI SAF are reasonably consistent, except for the exaggerated range effect shown by the VIC. The error bars on the DI SAF line in the range figure (4.6.2-2) represent the expected high and low hit probabilities for a trained soldier using an M-16 rifle at these ranges. These values were obtained from the US Army's qualification firing/record fire training documentation (*Unit Rifle Marksmanship Training Guide*, Osborne & Smith, ARI Field Unit, Ft. Benning, Georgia. May 1984). No data was provided for a range of 25 meters; this is not a defined range for this training (for the record, the target ranges extend to 300 meters for marksmanship training and test). These error bars were put on the DI SAF line since it was the only one within these prescribed bounds. As is evident from this graph, DI SAF performance is within the expected levels for a trained soldier, the VIC' performance is substantially below expectation. It is unknown but assumed that the soldiers participating in these experiments have achieved at least the minimal level of required proficiency. This data provides goals for improving VIC target engagement performance.

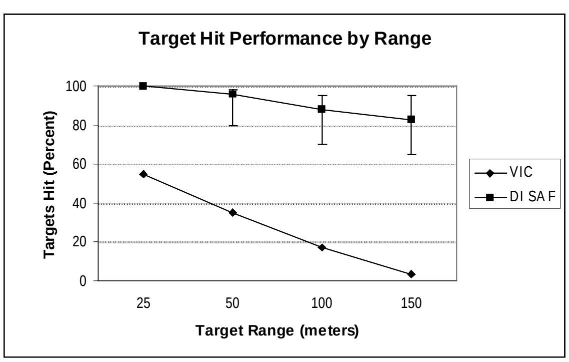


Figure 4.6.2-2. Percent Targets Hit by Target Range

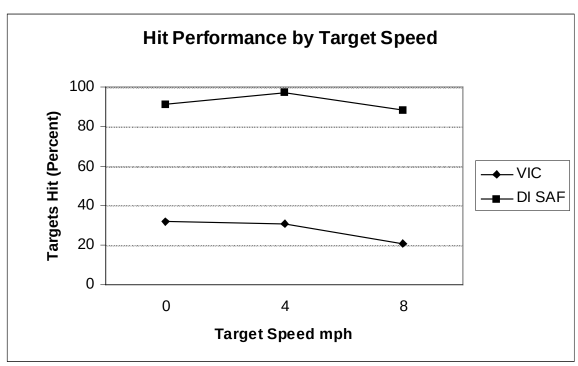


Figure 4.6.2-3. Percent Targets Hit by Target Motion

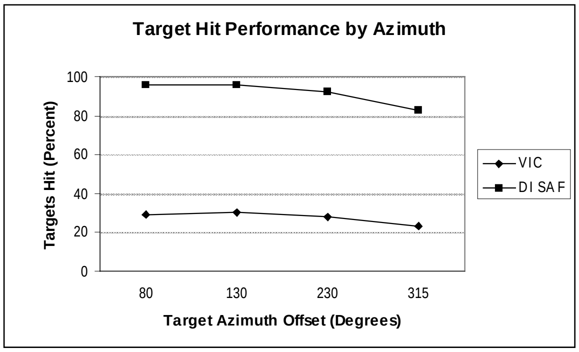


Figure 4.6.2-4. Percent Targets Hit by Target Azimuth Offset

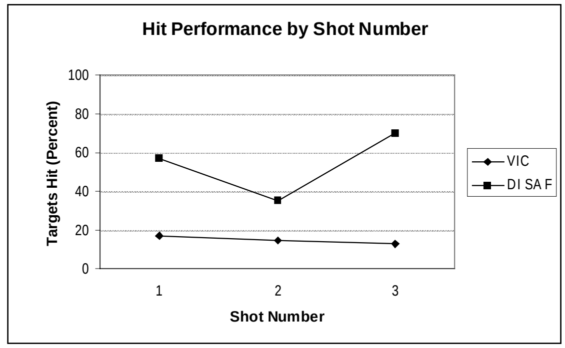


Figure 4.6.2-5. Percent Targets Hit by Shot Fired (1st, 2nd, 3rd)

The last graph, Figure 4.6.2-5, shows a marked difference between VIC and DI SAF success at each shot. VIC performance is relatively consistent since there were many misses and many more opportunities for second and third shots, so the probability of hit limit, given the aiming system performance constraints, had enough samples to be achieved. The DI SAF, on the other hand, had fewer trial exposures to begin with, hence fewer shots. Also, it had a high hit percentage, so second shots were fewer (31) and third shots fewer still (20). Thus, for the DI SAF, one hit plus or minus for the third shot represents a 5% change in hit percentage. So the observed differences do not appear to be particularly relevant to any significant performance issue.

4.7 Discussion and Lessons Learned

The aiming problems exhibited by three-quarters of the VICs during the DWN ERT engineering experiments provided an overshadowing presence during all testing. It is clear that this shortcoming will limit the utility of these simulators for dismounted infantry applications. RBD, the developer of the basic SVS system that is the core of these three simulators, is diligently working to solve this problem.

This is not to say that these simulators have no utility as they are. These same VICs were used prior to the DWN experiments by personnel from AMSAA and the LWTB to conduct experiments on short-range quick-kill hit percentages. They conducted trials within Building A of the McKenna database in which soldiers entered rooms containing enemy troops and engaged them with the simulator's weapon. Although aiming was off then, at the ranges that the targets were being engaged the soldiers could "Kentucky windage" their shots to hit the targets adequately for the purposes of the study.

One lesson learned was that the incremental and interrupted integration effort resulted in some problems for the tests. Some data (such as RBD's fire PDU velocity vector) that would have been useful for analysis was not fully verified. Dry runs of the engineering experiments could not be performed due to ongoing development, demo rehearsals, and actual demonstrations. This caused some initial confusion during the first day of the experiments, especially for the posture trials. A dedicated integration period of at least a week, without extensive development activity or distracting demos, is required to maximize productive experiment time.

The following sections will summarize the most relevant results from each of the experimental tasks along with any additional anecdotal information.

4.7.1 Locomotion

Objectively, the thumb transducers on VICs Alpha, Delta, and Echo provided an adequate mechanism for the soldiers to maneuver through the virtual environment. In no case did a soldier have to terminate a task because he could not move as he intended or get where he needed to go. During the search & engage task, there was some problem of control coupling, that is, when the soldier tried to rotate in place he would inadvertently introduce some forward motion as well.

Golf, using the ODT, did present challenges for a least some of the soldiers. It is slow and difficult to use. This seemed to be exacerbated by the use of the HMD in conjunction with the ODT. The ODT has more than adequately demonstrated its strengths and weaknesses as a soldier interface during two sets of DWN experiments. It should be relegated to its primary intended purpose as a research instrument.

The lack of visual depth and motion cues inside of buildings was previously noted. VIC Delta seemed to experience visual problems beyond those expected with a VGA-quality display. Delta was supposed to be able to run in SVGA mode with the Real3D Pro, but this was not achieved in practice. One possible problem for Delta was the attempt to dynamically change the FOV based on soldier position relative to the screen. There appeared to be some noise or other problem in this process, causing a dynamic blurring of the image and further resolution loss.

Alpha’s database problem, which was never adequately resolved, caused much frustration for the soldiers and inflated the route times and caused trial aborts. Soldiers would pop-up onto the roof of Building A from inside of the building, then would have to jump or be teleported to the ground to start over again.

Finally, collision of DI models with the environment needs improvement and standardization. Differences between the SVS systems and Alpha may be a cause of some differences in the collision data collected. From an operational and validity perspective, seeing troops with half of their bodies immersed in walls or door jams proved disturbing to the soldiers and visitors. Plus, during the user exercises, soldiers would sometime see weapons or body parts protruding through walls, giving away the locations of enemy in a manner not available in reality. This is a thorny issue in DI simulation, conceptually relatively simple to resolve from a visual perspective but computationally expensive to implement. In addition, there are user feedback issues (primarily haptic) that are extremely problematic.

4.7.2 Search

The projection display systems had a significant advantage over the HMD-based systems (Golf and Alpha). The wider FOV of Echo did not give it a significant advantage over VIC Delta in acquiring the array of targets presented. And while resolution differences between Echo and Delta did not appear to give Echo a significant range acquisition advantage in terms of acquisition times, it did so in the number of targets acquired at ranges beyond 50 meters. Even so, Echo’s performance was not substantially better than VIC Alpha’s in a number of measures of search performance. This is surprising considering the FOV and resolution advantages of VIC Echo. Why this is so is not clear.

4.7.3 Target Engagement

As stated in the introduction to this section, weapon aiming was a significant concern during the experiments. Performance was poor for the SVS-based systems, and Alpha's did not come close to that expected by even marginally proficient soldiers in the real world. Besides tracking problems, VIC Golf's weapon simulation within the HMD was always a problem. The developers had tried several approaches, none of which appeared to be very satisfactory. The implementation used by Golf during the experiments was the one in place when development efforts had to stop in order to conduct the experiments. Since the HMD version of the SVS was not part of their standard product, the aiming solution did not benefit from the same development history as did the base SVS.

Posture differences generally effected aiming performance for all VIC, with causes originating both from increases in tracking error and simulation effects due to the diminished eye height. The chief effect was found in the prone posture, as would be expected.

4.7.4 Inside/Outside Search

These tasks did not prove to be discriminators for assessing the visual search capabilities of the VIC. All VICs primarily missed targets that required looking ±90° off from the direction of travel. Most targets that required the VIC to search vertically were found.

4.7.5 Summary

Table 4.5-1, reproduced below as Table 4.7.5-1, shows overall VIC performance for each of the experimental tasks. The overall results indicate that the VIC Golf configuration is clearly not the best implementation for a DI simulator. The combination of the ODT, poor SVS aiming, a suspect weapon simulation, and an HMD in conjunction with the ODT, produced a simulator that fairly consistently placed last in task measures of performance. VIC Alpha faired surprisingly well in most tasks, primarily (but not solely) due to the fact that its aiming solution performed the best of all. The added FOV of VIC Echo did not seem to provide benefit in the search task where it would be expected to have the most impact. Once again (for the infinitieth time), better display resolution was proven to be advantageous to improved task performance. Databases, primarily inside of buildings, need better texture, lighting cues, etc. to facilitate depth and motion perception, and to be able to discern where in the building one is located.

Table 4.7.5-1. Overall VIC Task Performance Summary

			VIC			
Task	**Measure of Performance**	**Statistic**	**Alpha**	**Delta**	**Echo**	**Golf**
Locomotion	Time to Complete Course (Secs)	Mean	294.5	224.3	203.1	411.1
		S.D.	146.3	165.1	117.3	226.1
	Collisions	Number	835	230	283	257
Search & Engage	Time of 1st Shot (Secs)	Mean	12.9	10.5	9.9	13.4
		S.D.	4.4	4.1	4.0	4.5
	Targets Hit*	Percent	38.3%	24.7%	33.1%	14.8%
Posture	Targets Hit*	Total	63.5%	30.5%	35.2%	34.4%
		Standing	69.5%	35.9%	37.5%	36.7%
		Kneeling	64.1%	32.0%	46.9%	42.2%
		Prone	57.0%	23.4%	21.1%	24.2%
Search Inside	Targets Located	Percent	70.8%	83.3%	75.0%	62.5%
Search Outside	Targets Located	Percent	73.8%	73.8%	71.3%	42.5%

*Total targets possible = 384; 128 per posture.

5.0 User Exercises

5.1 Introduction

The DWN ERT User Exercises (USEX) were patterned after the previous DWN USEX. However, reflecting the MOUT focus of this phase of the DWN effort, the mission scenario was a building assault and clearing operation, as compared to both open terrain and MOUT scenarios during the prior DWN USEX. Also, as with the engineering experiments, the USEX was conducted over the course of one week instead of the three week period during DWN.

The USEX was conducted over the week of July 20 – 24. The same soldiers that participated in the engineering experiments also participated in the USEX. Additional soldiers from Ft. Benning and TRAC-Monterey also participated as platoon and squad leader role-players.

5.2 Purpose

There were two primary goals for the USEX. The first was to assess the operational utility of the four VICs when used within a goal-oriented mission context. The second goal was to assess how well the improved DI SAF could perform as an augmenting DI force, working in coordination with manned simulators to achieve the overall mission goal. These two purposes are discussed below.

During the engineering experiments, the intent was to evaluate elements of the simulations in relative isolation, looking at their locomotion, visual display and control, and weapon aiming subsystems. This was accomplished through the use of specific individual-level experimental tasks that employed only parts of the simulators at one time. The USEX was intended to provide a more holistic evaluation of the simulators. The goal was to provide a complex, real world mission setting that would require the use of all components of the simulator sequentially or in parallel as required by the tasks at hand. The evaluation rationale was that by providing a context that the soldiers were familiar with, they would be in a position to assess how transparent, or how difficult, the operation of the simulator was with respect to accomplishing a task he was used to accomplishing in the real world. These subjective assessments were the primary data to be recorded. Since four simulators were available for simultaneous operation, plus BAYONET stations for the role-players, the manned operational unit was limited to a fireteam.

A significant development effort was undertaken during DWN ERT to provide the DI SAF, begun under DWN, with the capability to conduct operational tasks inside of buildings. With the manned simulators limited to a fireteam unit and the scenario defined as a platoon operation, the DI SAF were tasked with filling out the platoon. This required the DI SAF to provide a fireteam to operate with the VICs to fill out a squad, plus “man” a separate squad to complete the platoon. Thus, the USEX provided an opportunity to compare ‘live’ (simulated live) soldier performance with computer-generated SAF behavior, and to experiment with the coordination of these two types of forces.

5.3 Experiment Plan Overview

The USEX planning began during the proposal process, with the basic scenario developed jointly by LMIS, LMTSG, STRICOM, SAIC, and infantry SME personnel forming a portion of our DWN ERT technical approach document. The scenario as it was finally defined for the USEX can be found in the DWN ERT Experiment Plan (Appendix B), along with other details of the USEX planning.

Basically, the scenario involves an assault on a building, then systematic search for and clearing of OPFOR snipers. The McKenna database, and specifically the southernmost two town houses of Building A, served as the scenario building. Dynamic terrain capabilities added to the VICs and DI SAF during DWN ERT supported the assault phase of the mission. An AT-8 was fired by the SAF at a wall on the south side of the building, which blew a man-sized hole in the wall. This breach served as the ingress point into the first room of the building, from which all further clearing operations progressed. Several closed doors within the building had to be removed using a SAW by either the VICs or SAF troops.

The scenario defines the progress of the mixed VIC and DI SAF squad and the pure DI SAF squad through the building. It was planned to rotate the VICs through the three other fireteam positions to provide variety over repetitions of the scenario. As it turned out, the impact of the sniper fire on the SAF portion of the platoon, and the VICs' response to these changes in force structure, provided enough variation in the execution of the scenario that this rotation was not required. The sniper, played by a manned BAYONET station, could relatively easily take out an entire fireteam of SAF (or even a squad if allowed). Once a SAF fireteam was lost, the squad and platoon leader role-players dynamically re-allocated the VIC fireteam to compensate for this loss. Since the SAF followed scripted paths that were not easily modified, the VICs alone were required to modify their plans.

The primary data collected was soldier subjective assessments. The forms used for this data collection are presented in Appendix C. The development of these forms, their administration, and the summarization of the data are primarily the responsibility of the ARI office at Ft. Benning.

Finally, the communications networks designed for the USEX (see Figure 2.2-2) were abandoned in favor of a single network at the request of the platoon sergeant and platoon leader role-players. The workload introduced by having to remember to switch channels (and remembering which channels to switch to) added to that already experienced in having to use Bayonet and monitor soldier activities proved to be too much.

5.4 Results

As noted, ARI Ft. Benning had the primary responsibility for data collection during the USEX. Their assistance in the execution of both the USEX and the engineering experiments was invaluable and is very much appreciated. They are currently performing the summarization, analysis, and interpretation of the results of the DWN ERT USEX, and will be publishing this in the near future. In the meantime, they have graciously provided LMIS with interim summaries of both the questionnaire results and the results of interviews conducted at the end of the USEX.

These summaries will be provided in this section of the report as they were received (modified to black and white and re-scaled). Limited interpretation of these results and other anecdotal information gathered during the USEX will be discussed in the following section.

5.4.1 Questionnaire Data

The following Figures 5.4.1-1 through 20 show the soldiers' responses to the items presented in the questionnaires. The 'y' axis represents number of responses for each category; the 'x' axis represents rating categories correlating simulator performance with that experienced in the real world.

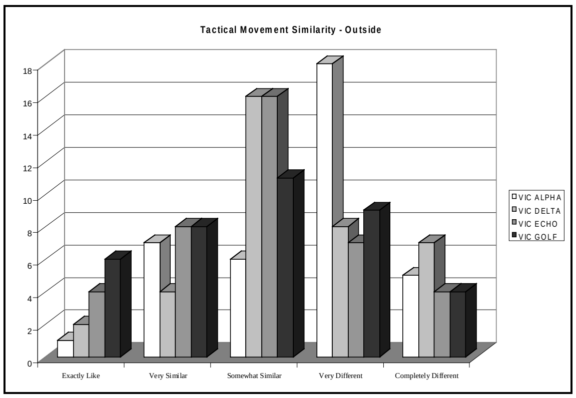


Figure 5.4.1-1. Tactical Movement Similarity Ratings - Outside

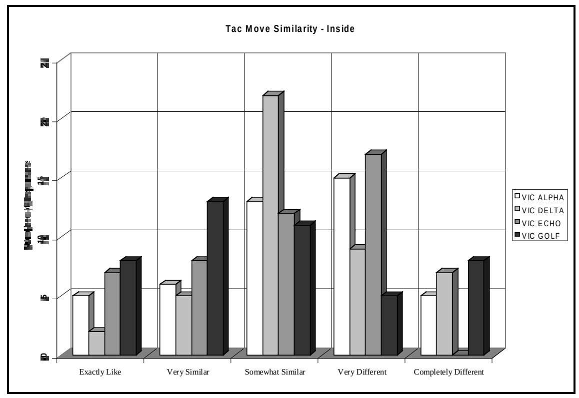


Figure 5.4.1-2. Tactical Movement Similarity Ratings - Inside

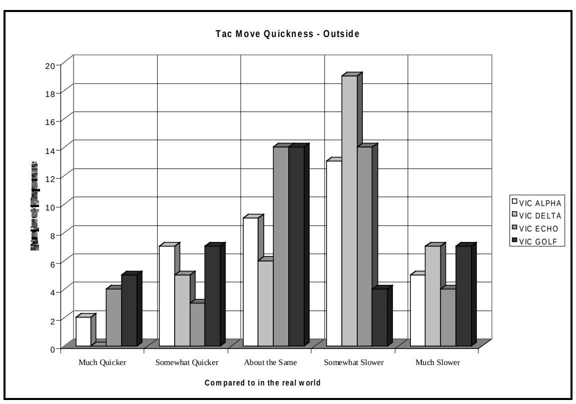


Figure 5.4.1-3. Tactical Movement Quickness Ratings - Outside

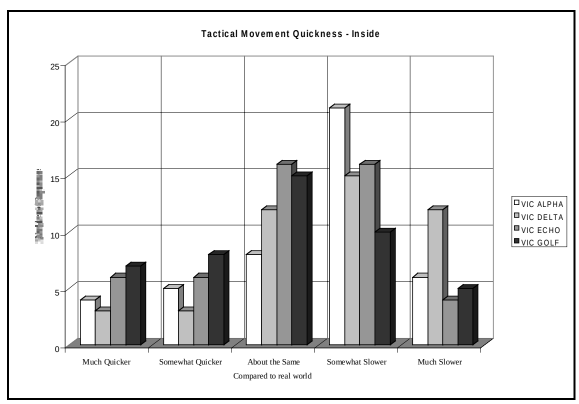


Figure 5.4.1-4. Tactical Movement Quickness Ratings - Inside

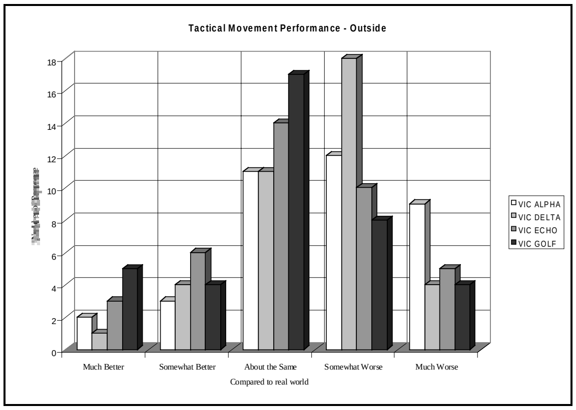


Figure 5.4.1-5. Tactical Movement Performance Ratings - Outside

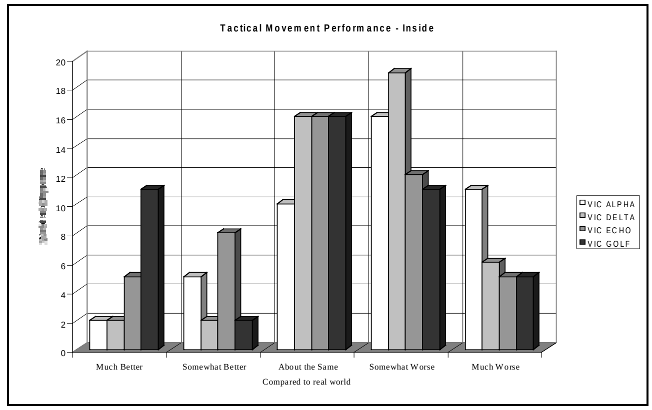


Figure 5.4.1-6. Tactical Movement Performance Ratings - Inside

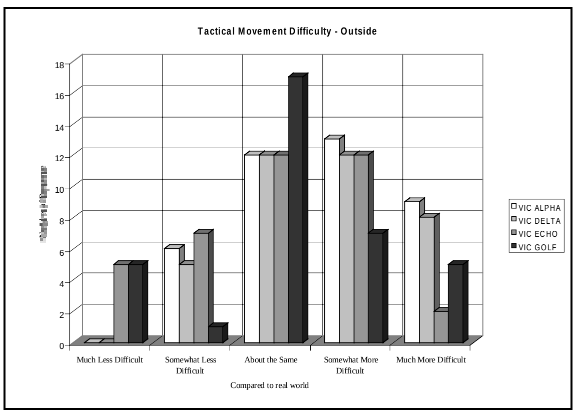


Figure 5.4.1-7. Tactical Movement Difficulty Ratings - Outside

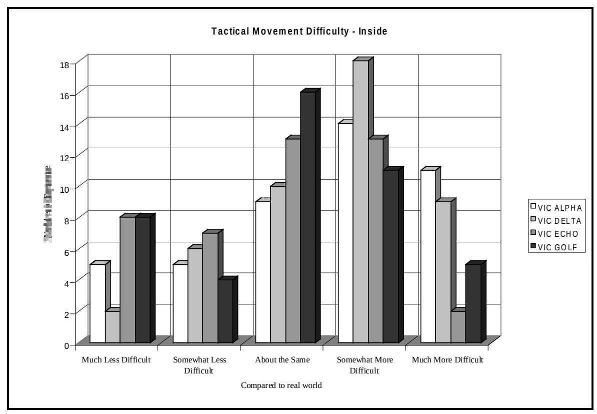


Figure 5.4.1-8. Tactical Movement Difficulty Ratings – Inside

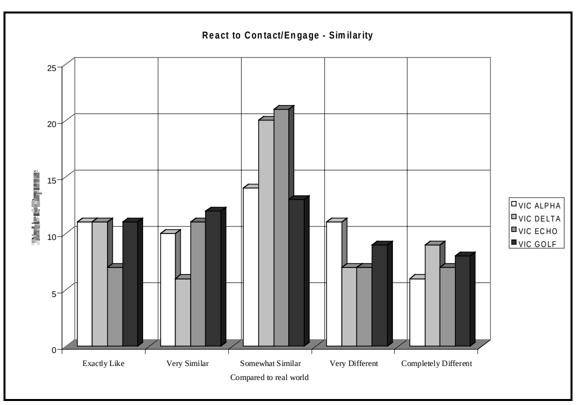


Figure 5.4.1-9. React to Contact and Engage Similarity Ratings

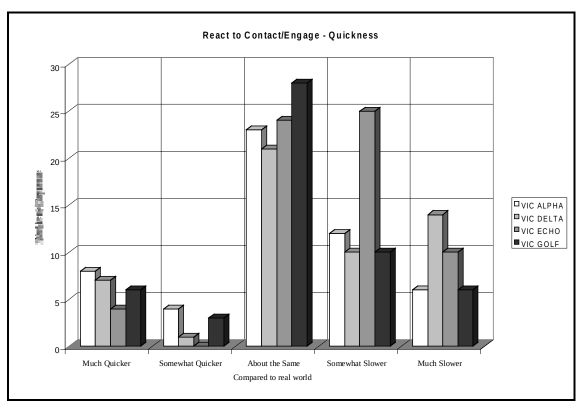


Figure 5.4.1-10. React to Contact and Engage Quickness Ratings

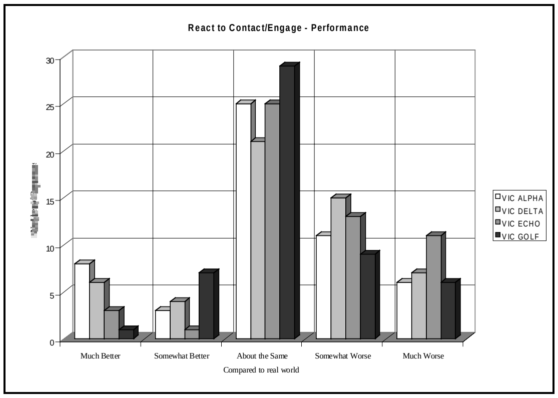


Figure 5.4.1-11. React to Contact and Engage Performance Ratings

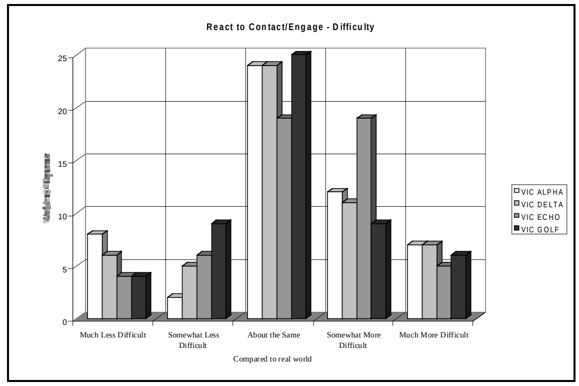


Figure 5.4.1-12. React to Contact and Engage Difficulty Ratings

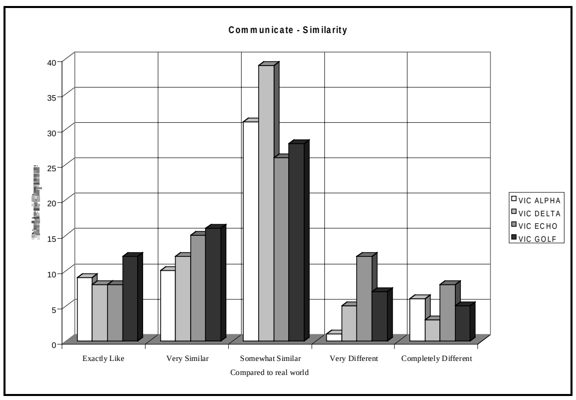


Figure 5.4.1-13. Communication Similarity Ratings

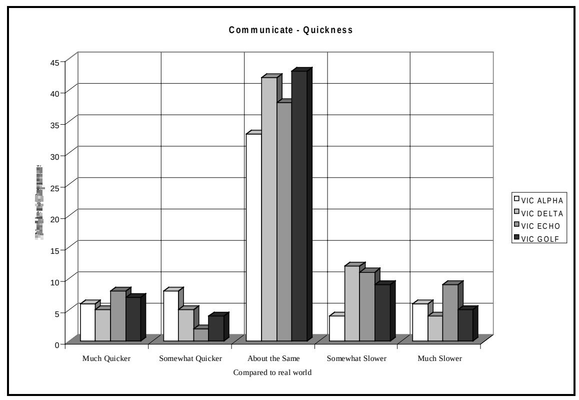


Figure 5.4.1-14. Communication Quickness Ratings

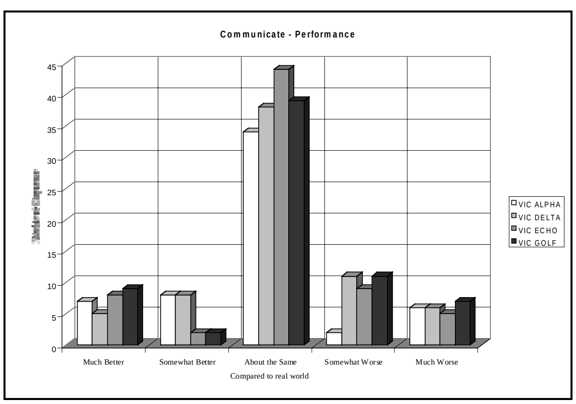


Figure 5.4.1-15. Communication Performance Ratings

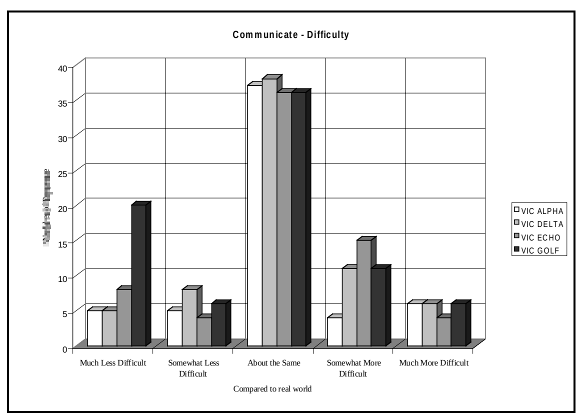


Figure 5.4.1-16. Communication Difficulty Ratings

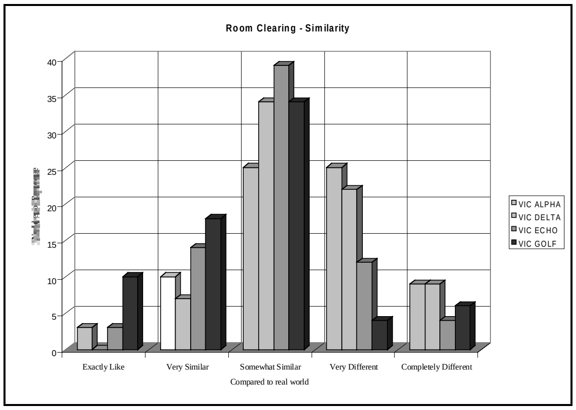


Figure 5.4.1-17. Room Clearing Similarity Ratings

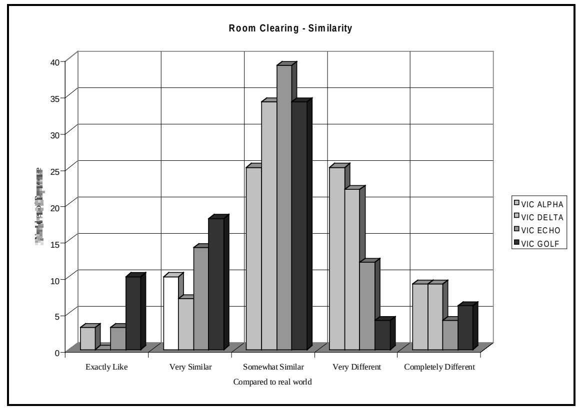


Figure 5.4.1-18. Room Clearing Quickness Ratings

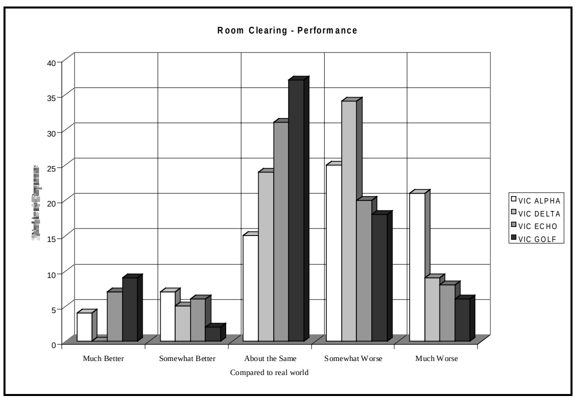


Figure 5.4.1-19. Room Clearing Performance Ratings

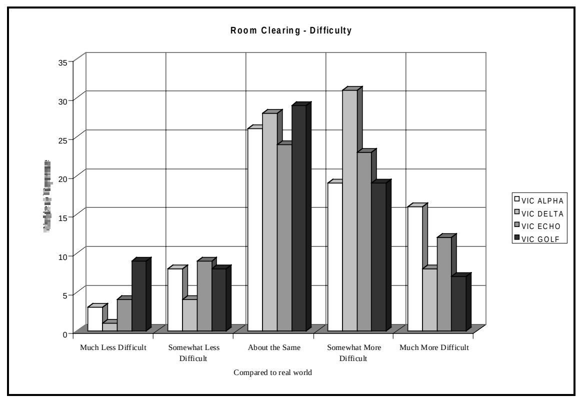


Figure 5.4.1-20. Room Clearing Difficulty Ratings

A general observation is that the majority of responses seem to fall in the "Somewhat Similar/About the Same" middle rating and the "Somewhat Different/Slower/Worse etc." rating. This would indicate a neutral to somewhat negative impression of simulator performance as compared to that in the real world. This appears to hold for all the VICs.

5.4.2 Soldier Interview and Comment Summaries

At the end of the USEX each soldier was thoroughly debrief by a member of the ARI team using the structured interview form. Responses covered both the engineering and USEX portions of the experiments and represent the soldiers' views as well as ARI comments on simulator reliability and other anecdotal information. The summaries provided by ARI to LMIS are reproduced below and have been edited for style only. ARI acknowledges that these are draft versions of the summaries; final versions will be included in their report. First-draft versions of the actual subject responses to the structured interview questions were provided to LMIS by ARI, but are not included here due to their preliminary nature.

5.4.2.1 VIC Alpha

Search and engage trials seemed to yield generally positive comments and results regarding target acquisition and firing of rifle. Negative comments were noted in reference to joystick position being awkward, IHAS display blurring, targets staying up after being killed which resulted in two targets being in view when new target released, and arm and hand appearing in front of rifle in visual display. A delay between pulling the trigger and actual firing of the rifle also produced some difficulty in striking targets, particularly at longer ranges. Interestingly, using the IHAS created far more problems in identifying and striking targets than did use of iron sights. Complaints were voiced about the target "jumping around" within the visual display, and about the aim being as much as 45 degrees off when using the IHAS. However, accuracy without the IHAS was much better, relative to that of other simulator's weapons systems. Most annoying to participants was frequent down-time for calibration of the rifle, as well as the relative difficulty in preparing to use this simulator. Excessive battery usage *(for the weapon fire signal transmitter on the rifle)* appeared to be a significant detriment with this machine, which resulted in frequent interruption of trials.

Missions to assess locomotion aspects were very difficult to perform in this simulator due to the soldier's representation (icon) becoming "stuck" in walls, teleporting through walls into other areas or buildings, and teleporting through the roof, with particular difficulty noted while attempting to negotiate stairwells. These recurrent problems generated many expressions of frustration and disgust by participants. They also produced unrealistic scenarios when the VICs were networked as a fire team and each participant had an area of responsibility to cover. Participants in this VIC frequently broadcast radio communications such as "I'm on the roof again" or "I fell through the wall". Additionally, the Alpha icon would simply disappear from the view of other participants whenever he teleported, which is extremely unlikely to happen in the real world. Other fire team members were observed attempting to direct VIC Alpha through a scenario by informing him that he was stuck in a wall, or by making similar navigational suggestions. One soldier was observed looking to VIC Alpha's monitor screen, which was within his field of view, and yelling navigational directions to the soldier in VIC Alpha before being asked to desist from this behavior. It is doubtful that any of these factors contributed to the overall realism of the vignette being simulated. Outdoor maneuvering and visualization of targets in the MOUT environment appeared to be relatively good with this VIC (Search-Out trials), but calibration issues continued regardless of the type of trial.

One of the more obvious issues related to training is that if a soldier in this simulator is expected to be an active participant in a fire team mission, then it will be necessary to resolve the problems with locomotion and maneuverability. It will also be necessary to take steps to correct the battery and calibration problems that resulted in frequent interruption of mission participation. Only on rare occasions was this simulator fully functional throughout the course of any trial.

5.4.2.2 VIC Delta:

In search and engage trials, positioning of the soldier within the VIC was a major factor affecting the ability to acquire and engage targets. This was especially apparent in the prone position. While in the prone position, the soldier's field of view was represented as being below the horizon, and any rounds fired struck the ground immediately in front of the soldier. The only available remedy for this particular glitch was for the soldier to stretch up on his elbow in an awkward and unnatural manner, so that he would be registered by the sensors as being above the horizon. Weapon sighting was also a major source of frustration for soldiers in this VIC. When using iron sights the rifle was so inaccurate that targets were missed at point-blank range on several occasions. This led to soldiers making only a cursory attempt to aim the rifle, particularly if the target was presented at long range. These factors led to soldiers commenting on how frustrating it was to participate in target acquisition trials in this VIC. Adding to the frustration was the soldier's inability to compensate for the inaccuracy by using Kentucky windage techniques. This was due to inconsistency in the degree of inaccuracy from target to target, and trial to trial. However, in trials in which the IHAS was employed, accuracy and subsequent satisfaction of participants were greatly improved.

Locomotion trials were performed with relative ease in this VIC, with the emphasis on relative. Most soldiers agreed that this was among the easiest to maneuver in, although there were some glitches observed and reported. Taller soldiers often had difficulty with being picked up by position sensors and were frequently observed looking up at the sensor antenna to check their position. It was also necessary for all soldiers to look down and make sure they had not moved past a tape-line on the floor, beyond which their position would not be accurately registered. Additionally, whenever soldiers inadvertently moved beyond this line the visual display would become blurred and distorted, rendering it useless. On a few occasions the icon would jump through walls or get stuck in the stairwell, but this occurred very infrequently.

Outdoor locomotion and stacking maneuvers were excellent with this VIC, in keeping with its overall ease in maneuvering. While no VIC was rated as more than somewhat similar to the real world in tactical movement by more than a few individuals, this VIC did rate highest in most movement items on the questionnaire.

Some complaints were voiced regarding hand and wrist fatigue related to joystick manipulation. This was particularly evident in search and engage trials, but such observations were relatively infrequent. Overall integration with other VICs was fair, although problems were observed with icons levitating and disappearing and reappearing in the visual display. It was also very difficult to move around or near other virtual soldiers in the visual display.

5.4.2.3 VIC Echo

Search and engage and posture trials produced similar observations to those noted with VIC Delta. The ability to aim the rifle accurately and strike the target was severely limited, particularly in the prone position. In this position the sensors appeared to place the soldier below the horizon, resulting in shots striking the ground directly in front of the soldier, when it could be seen at all. Detection of distant targets was very difficult. An extremely small percentage of targets fired upon from the prone position were hit. These results were not much improved in the kneeling or standing positions due to poor calibration of aiming sights. When the IHAS was employed, results improved dramatically. It was observed that when the IHAS was in use, the rifle could be oriented from 45 to 90 degrees away from the target, but the target would be hit. This degree of inaccuracy was not consistent in any trial, and created a great deal of difficulty in hitting targets without using the IHAS. Some soldiers were observed holding the rifle above their heads in a very unrealistic manner in an attempt to compensate for the horizon problem, in both the kneeling and prone positions.

Locomotion trials produced generally favorable reactions overall regarding this VIC, in terms of subjective comments and questionnaire responses. There were several complaints noted in reference to locomotion with the IHAS engaged. Most participants stated that it was very difficult to maneuver with the IHAS down, and nearly all were observed flipping the IHAS up when walking, then back down when it was time to aim the rifle. Most soldiers observed that this was very time consuming and unnatural, with one individual stating, “In the real world, having to flip this thing up and down all the time would eventually get me killed.”

Technical problems occurred with the projection system on a few occasions, with one of the three panels turning green or going blank. Additionally, vertical lines sometimes appeared between the three screens. Integration of systems was also intermittently problematic. The position of the VIC Echo icon was often misrepresented on the visual display of the other simulators, including the Bayonet machine that was operated by the squad leader. This misrepresentation resulted in the impression that orders were not being followed and that the participant in VIC Echo was out of position during fire team exercises, when in fact he was not.

5.4.2.4 VIC Golf

The true effectiveness of this VIC is difficult to determine due to the fact that it was so infrequently fully operational. Most soldiers had at least some difficulty becoming accustomed to maneuvering on the omni-directional treadmill (ODT). This led participants to focus on the physical act of walking and maintaining balance, which diminished their ability to effectively participate in trials. Some participants were heard saying they were more concerned with falling than with completing the mission. A few soldiers were able to develop a relatively high degree of competency in maneuvering on the ODT, but other problems of a technical nature persisted. These included the ODT clutch engaging, which effectively stopped trial participation, as well as other technical glitches that often interrupted trials. This frequently necessitated abandonment of ODT usage in favor of joystick controlled movement. In any case, it was quite difficult for the participant to determine his physical position, e.g. prone, kneeling, standing, which led to additional problems in maneuvering. At one point, a soldier was heard to ask why he was moving so slowly. The operator told him that it was due to his being in a kneeling position. The soldier had thought he was in the standing position. Soldiers also had frequent problems with becoming entangled in the harness apparatus, particularly when attempting to turn. Frequent problems were noted with maneuvering, with the soldier’s icon becoming stuck in walls, with particular difficulty observed when attempting to negotiate doorways and stairs. The icon often was transported through walls to the outside of the virtual building, or to underneath the stairs.

In regards to weapon and aiming systems, there were several problems observed. The most immediately apparent was the visual representation of the rifle in the IHAS. The rifle appeared to be floating at an odd angle in front of the soldier, in a manner that is patently inconsistent with reality. When aiming the weapon, soldiers were forced to hold the rifle at a difficult angle in order to fire, e.g. with the stock extended laterally off the shoulder approximately six inches. There was a recurrent problem with the magazine falling out of the rifle, which necessitated stoppage of participation to retrieve it. The instability of the ODT contributed additional difficulty in acquiring and aiming at targets. Soldiers reported that they would get a target lined up, then the ODT would jerk, causing them to lose sight of the target. Additional observations involved the flickering of distant targets and poor calibration of IHAS sights. Most participants expressed overall dissatisfaction with the weapon and aiming systems on this VIC.

When conducting integrated fire team exercises, there were problems with this VIC being unable to keep up with the team. When stacked in a room, the visual display in this VIC often failed to display other fire team members in the room. Inability to determine body position also caused problems in integrated team mission. This would lead to fire team members standing on top of one another's icons, and this often led to teleportation problems and levitation of icons.

5.5 Discussion and Lessons Learned

Most of the soldier comments and ARI observations are consistent with the observations and findings of the engineering experiments. A few other issues that were identified that have not been discussed yet are included here for completeness:

1. The DI-Guy "quick-kill" posture. This was an ongoing development challenge for BDI, one that they never quite resolved during the experimental period. When the DI-Guy was stationary, there was some inherent noise within the model that caused the weapon to rotate slightly, along with the model's hands and arms. This stirring-type motion made the animated character appear as if it had palsy, or was performing a little dance to music only it could hear. Also, in the weapon deployed posture, the hand was not on the weapon, but was grasping the air beside the rifle stock. Finally, thresholding the transition between the standing and moving postures needed tuning, there was a lot of 'flickering' between postures when the soldiers were standing still.

2. Tracking problems made it difficult for soldiers in Delta and Echo to assume the desired posture, e.g., kneeling. In several instances, soldiers were instructed by the platoon/squad leader to kneel down. The soldiers did; but their icons did not represent this – they still appeared standing. The leaders would yell at them to get down and they kept insisting they were, which they in fact were.

3. The collision detection algorithms in the SVS systems quite often resulted in soldiers walking or jumping over standing soldiers who were in front of them. In close quarters with a fireteam or squad of soldiers, this resulted in many instances of soldiers appearing to pop up and down over and on top of one another. Collisions, as noted earlier, were a problem for VICs and SAF alike.

While it is apparent from the above and indeed much of the entire report that much work remains to be done on dismounted infantry simulations, it should be noted that this is perhaps the most challenging of all virtual simulation areas. The software and hardware technology growth requirements are possibly the greatest in this area; perhaps that is one reason it is the last area of military simulation to be developed. It would be a grave omission if the contributions of the participants in this and previous DWN efforts were not adequately acknowledged. It takes courage to attempt something difficult and then allow it to be subjected to the critical scrutiny of others. While this risk taking and openness has long been recognized and often taken for granted within the DWN team, it is hoped that everyone who reads this report will appreciate it as well.

Towards this end, one section from the structured interview will be presented. This is the soldiers' responses to the initial question "What was the best thing about each VIC?" The responses presented below have been edited from the text given to LMIS by ARI in order to make it more readable. While some material has been added or deleted, the overall intent of the answers has not been altered.

WHAT WAS THE BEST THING ABOUT . . .

Alpha

Aiming was realistic; you hit targets when they lined up in the sight post. I liked being able to turn around and have my own movement changing the view. It gave me a 360-degree view of everything as I moved through the mission. I could turn my head and my body and this made the whole thing feel real. It provided me with good peripheral vision. The front sight aperture made the weapon feel very (real) - seeing the front sight when I fired made the weapon feel real. In addition, the actual weight of the weapon made it feel very real…like carrying a real M-16 rifle.

Having my hands and feet connected to the system (*i.e., tracked and displayed*) was good, I can kneel and move left to right. Moving my body was better than using a joystick, better than spinning and moving your body with one. The shooting capability—the aiming—I shot best on that one. That and freedom of motion, ability to rotate 360 degrees. It has a better view, although sometimes it keeps blinking off. The sight post on the front of the weapon made the weapon feel real…. It felt like aiming and firing a real M-16. This rifle felt more realistic than the other rifles because of the weight and the front sight. The movement on it felt realistic… I like being able to look around corners and to the left and right.

Delta

This VIC was the easiest to operate. The joystick allowed me to move through the building very fast. I liked the IHAS because it allowed me to look around corners and engage targets. I also liked it because it forced me to kneel and lay prone. When I wanted to kneel, I really had to take a knee, rather than just push a button to simulate taking a knee. This made it feel somewhat real.

Aiming and movement -I had no problems with Delta. The joystick allowed me to move faster than any of the other VICs. I could see more of the picture and get a better feel for things. I had a good field of view. I liked the IHAS, that was the best of any of the machines. I could move and maneuver well; glide through doors and upstairs. The IHAS aims easily. There was no background noise with commo. It also had a good reload simulation. Aiming was about the same as in the real world –just point and shoot. Looking and moving up and down - your body mimics the real world although you are not connected. Your eyes equal your soldier's eyes. It was easier to maneuver - liked the IHAS.

Echo

I liked the wide field of view and the display was the clearest. Like Delta, it was easy to move in it and I liked the IHAS. I liked the 180 degrees of vision it provided. The 180-degree effect provided me with good peripheral vision when it came to identifying targets and seeing objects. My movement in Echo felt more realistic. I also found that I could not get stuck in walls as easily as I could on the other VICs. The IHAS provided me with very good sighting and it allowed me to fire my weapon more accurately. You are in there surrounded by screens – the audio is awesome. Good reload simulation. You can kneel without a button. Everything is good – you can peek around a corner, can move well, really get into it. I liked the field of view although it made me dizzy sometimes and the walls seemed close. With the big screens it was easier to go through doors. I like the IHAS. Movement capabilities were good. It provided good peripheral vision and I liked the idea of being able to look left and right for 180 degrees. The IHAS was great for sighting and firing. It was very easy to catch things out of the corner of my eye without having to turn my head or my body. It gave me a wide view and this made it easy to spot targets.

Golf

Being able to physically run and walk gave me a sense of movement that made the mission seem more real. It gave me the physical sense of moving through the building. This added a small degree of realism to the mission. It made me feel as though I was actually walking and running. The view was good. This VIC gave me a very good sense of actually engaging in physical movement. It made the feel of walking through the mission real. I also liked the way the HMD fit and felt on my head. The treadmill was fun, but that's not applicable to the project. I just liked it. Sometimes moving on the treadmill actually got me hyped up. I moved my body like in real life. It also feels like all your normal equipment is on.

There were no specific comments by the soldiers on the DI SAF. The SAF's reaction to enemy fire was not very effective, so that usually when the SAF encountered the sniper, he would kill most or all of them as they kept coming around a corner or into a doorway. The VICs often used the stack of SAF bodies to identify which room the sniper was in. Overall, inasmuch as the SAF's routes, terminal locations, search patterns, and postures were completely programmed *a priori* by the SAF operator, their behavior during the execution of the scenario was reasonably well-behaved and realistic.

6.0 Implications of Experiment Results

The major implication of the current experiments should be exceptionally obvious by now – the SVS-based simulations need to improve their aiming technology. The less obvious part of this is the answer to the question "How good does the aiming have to be?" The operationally easy answer is to make it as good as the weapon – this in effect eliminates the need to ask the question at all. However, this is clearly not a cost-effective solution. What the correct answer should be is beyond the scope of this report.

Among the four VICs, the VIC Golf configuration with the HMD, virtual weapon, and ODT, proved not to be a viable candidate. The ODT's limitations were known from previous experiments, and since no development was conducted on the ODT during DWN ERT, these limitations were once again identified. Incorporating an HMD with the ODT made its operation more difficult, since the added cabling made 360 degree movement impossible. The weapon aiming solution initially used proved to be inadequate. Thus, there is little to recommend continued operation of this VIC. That it has now be relegated to be a research tool better fits its original intent and present capabilities.

VIC Alpha fared better by comparison during DWN ERT than it had previously in DWN. The non-visible light made it less intrusive within the overall simulation system, and it proved to be more reliable than in the past. However, reliability was still an issue, and its database problem causing soldiers to pop-up onto the roof and get stuck in walls hindered its acceptance by the soldiers. Its whole-body tracking provides the raw data to assist in overcoming the problems identified with collisions in tight spaces, a solution that is needed for MOUT operations. Implementing any such solution, however, poses problems that may be as difficult to overcome as the problem it is trying to solve. These include processing power requirements and presentation of necessary haptic feedback to the user.

VICs Delta and Echo, if their aiming problems are disregarded, present the most cost-effective alternatives of the VICs used during these present experiments. It is beyond the scope of this report to assess if they are the best or most general solution to DI simulation in general. VIC Echo, with a display system that is by most measures significantly better that that used by VIC Delta during the current experiments, did not prove to yield corresponding improvements in soldier performance. Objective data obtained during these experiments do not appear to justify the added expense that a dome segment display such as VIC Echo's represents.

For both Delta and Echo (and Golf also), the use of the Real 3D Pro image generator proved to be an impediment to development efforts. The intent was to overcome the inadequate update rates seen in the base SVS within the McKenna database (as low as 5 Hz, approximately). Use of the Pro ultimately did increase the update rate performance (to around 12 Hz), but its integration was difficult and time consuming, and ultimately resulted in less than optimal performance in other areas.

Stepping back for overall assessment of VIC performance in the original DWN scenarios as compared to that during DWN ERT, it could be argued that for the current state of DI simulation, within-building MOUT operations may be pushing the envelope a bit too aggressively. If aiming can be improved, then perhaps the best immediate use of these DI simulators is for open terrain applications, including MOUT assault-type applications.

Finally, DI SAF proved its potential for force augmentation at the individual, fireteam, or squad level. Automation of route generation and building search processes would enhance DI SAF utility. Validation of behaviors and human performance models would both enhance SAF credibility and could help serve as a basis for validating other simulations, such as the VICs.

7.0 Attachments

Appendix A: Model Data Questionnaire Responses

Appendix B: Experiment Plan

Appendix C: Experiment Questionnaire Forms

Appendix D: Acronyms